DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

NEW ZEALAND JOURNAL OF SCIENCE AND TECHNOLOGY

A. AGRICULTURAL RESEARCH SECTION

VOLUME 38.—No. 1 JUNE, 1956

Printed for the Department of Scientific and Industrial Research, Wellington,
by
Coulls Somerville Wilkie Ltd., Wellington, N.Z.
JUNE, 1956

COMMONWEALTH MYCOLOGICAL INSTITUTE
7 - AUG 1956

REGISTERED AT G.P.O., WELLINGTON AS A MAGAZINE

N.Z. J. Sci. Tech. A38(1): 1-108. Wellington. June 1956.

NEW ZEALAND

Journal of Science and Technology

VOLUME 38, No. 1, 1956

(AGRICULTURAL RESEARCH SECTION)

CONTENTS

	PAGE
A Uniformity Trial with Monozygous Twin Cows. *M. R. Patchell*	1
A Note on an Outbreak of *Verticillium* Wilt in a Nelson Hop Garden. *T. Christie*	15
Pathogenicity Tests with Species of *Verticillium*. *T. Christie*	17
The Use of Dried Buttermilk as a Complete Replacement of Whole Milk for the Rearing of Young Dairy Calves. *D. S. Flux* and *M. R. Patchell*	20
The Effect of Aureomycin Supplement on the Growth and Health of Young Calves. *M. R. Patchell*	23
Seed Disinfection. XIII. *H. Jacks* and *I. A. M. Cruickshank*	27
Resistance of Swedes to Aphids. II. *T. P. Palmer*	30
The Use of Chemical Thinning Sprays on Apple Trees in New Zealand. III. *R. M. Davison*	34
The Use of Chemical Thinning Sprays on Apple Trees in New Zealand. IV. *R. M. Davison*	41
Effect of Various Growth-regulating Substances on Fruit Drop and Storage Life of Apples. *R. M. Davison*	45
Thrips Infesting Cocksfoot in New Zealand. I. *K. M. Doull*	52
Thrips Infesting Cocksfoot in New Zealand. II. *K. M. Doull*	56
Effect of Steam and of Soil Disinfectants on Yield and Quality of Nelson Glasshouse Tomatoes. *D. J. Stanton*	66
The Rate of Growth of Short-rotation-ryegrass Pastures in the Late Autumn, Winter, and Early Spring. *R. W. Brougham*	78
Goitrogenic Effect of White Clover (*Trifolium repens*. L.). *D. S. Flux, G. W. Butler, June M. Johnson, A. C. Glenday*, and *G. B. Petersen*	88
Observations on the Biology of Calliphorids in New Zealand. *M. D. Murray*	103
Publication Received	108

NOTICES

SUBSCRIPTIONS.—Subscriptions payable in advance. Section A, 18s. per annum; Section B, 18s. per annum; A and B, 36s. per annum. Single copies, 3s.; postage, free. Sections A and B are published in alternate months. Subscriptions should be paid by money-order, postal note, bank note or cheque, and should be forwarded to the Publications Officer, Department of Scientific and Industrial Research, P.O. Box 8018, Wellington. Cheques should be made payable to the Department of Scientific and Industrial Research, and when payable at banks other than in Wellington should have exchange (6d.) added. Subscribers are requested to furnish their full names and addresses.

CORRESPONDENCE.—All communications relative to the Journal should be addressed to the Editor, Department of Scientific and Industrial Research, Wellington.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

NEW ZEALAND JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME 38

A. AGRICULTURAL RESEARCH SECTION

NEW ZEALAND
JOURNAL OF SCIENCE
AND
TECHNOLOGY

Department of Scientific and Industrial Research, Wellington
Editor: M. A. Black.

VOL. 38. SEC. A June, 1956 Number 1

A UNIFORMITY TRIAL WITH MONOZYGOUS TWIN COWS

By M. R. PATCHELL, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 2 August 1955)

Summary

1. The results from a uniformity trial on milk production and composition using monozygous twin animals are discussed.

2. Efficiency values are given showing the relative efficiency of twins as compared with ordinary unrelated animals. On the basis of the sample of twins studied one set of monozygous twins may replace without loss of statistical efficiency two groups of the following numbers of randomly selected animals.

Total energy yield	3.2
Milk yield	4.6
Butterfat yield	5.5
F.C.M. yield	4.3
Solids-not-fat yield	3.9
Total protein yield	3.5
Lactose yield	5.2
Butterfat percentage	23.3
Solids-not-fat percentage	8.0
Total protein percentage	12.6
Lactose percentage	1.2

Such efficiency values are subject to large sampling errors, but best indicate which characteristics may be profitably studied by the use of monozygous twins. It should be remembered that, because of interaction between genotype and environment and also the necessity to include an adequate sample of the population, the number of sets of twins necessary for an experiment may be greater than suggested by these figures.

3. The value of monozygous twins for genetic studies is discussed.

INTRODUCTION

The introduction of new methods of approach to the solution of research problems calls for detailed investigation into the relative efficiency of new methods and those used previously. The use of identical twins for milk production studies comes into this category. Since the members of a set of such twins are of the same genotype it is possible to obtain a measure of the extent to which the observed variation in

any particular character being studied is governed by heredity and environment. This is important in breeding work, where knowledge of the differential effects of different environments on different genotypes, i.e., of the interaction between heredity and environment, is useful when planning breeding policies.

In many experiments in which the effect of various treatments is being studied, the treatment differences can be tested statistically much more efficiently than is normally the case with experiments on ordinary animals. By using twin animals, differences in treatments due to hereditary differences between animals can be eliminated with a consequent reduction in the error variance which is used to test treatment differences. In many experiments, environmental influences should be strictly controlled but under New Zealand grassland farming conditions it is difficult to eliminate all environmental influences other than those directly imposed by design. In employing twins, however, provision has to be made for permanent differences that may exist between members of a set of twins, such, for example, as those differences resulting from the initial cleavage of the ovum and pre-natal environment. These and other factors are reviewed by Hancock (1950). A uniformity trial in which all animals are observed under the same conditions of nutrition and management enables an estimate to be made of the influence of such uncontrollable factors on the efficiency of twins for experimental purposes.

In order to obtain definite information on the usefulness of monozygous twins relative to cows selected at random for experiments on milk and butterfat composition, a uniformity trial with twins was carried out at this Institute during the 1951/52 season. This paper describes the results obtained in respect of milk production and composition. The work on butterfat composition will be described in a later paper.

MATERIAL AND METHODS

Animals

Ten sets of monozygous twin cows of varying ages were included in this study. The animals were originally collected from dairy herds in the Manawatu district as calves a few days old, and were reared on whole milk for the first 4 weeks, and then on skim milk until weaning at approximately 220 lb. live weight. The calves were grazed continuously on good quality pasture.

When the twins were collected it was not possible to obtain information on the exact breed or productivity of the parents, but no beef types were used. Thus the animals included in this study represent a small sample of a cross section of the dairy cow population in the Manawatu area. Animals all of the same age were not available and the inclusion of different age groups of animals could not be avoided. The differences within twin sets in calving times were small.

Some of the twins had been used for nutrition experiments during previous year's treatments on the results obtained during the 1951/52 season some had been subjected to a low plane of nutrition for a six-week period after calving. Statistical analysis failed to show any effect of the previous year's treatments on the results obtained during the 1951/52 season.

Feeding and Management

The animals were fed on pasture throughout the experimental feeding period, but during periods of pasture shortage, particularly over the summer months, the animals received as supplements a little grass silage and chou moellier (marrow-stem kale).

The weight of milk from each cow was recorded at each milking. On each of two consecutive days of each week, composite samples of milk from the p.m. and a.m. milkings from each cow were taken for the determination of the butterfat and total solids contents. On similarly drawn samples the total protein content of the milk was determined once each week and the lactose content once each fortnight. Butterfat, total solids, and total protein percentages, were determined by Gerber, gravimetric, and Kjeldahl methods respectively, and lactose percentage by McDowell's (1941) modification of Lane and Eynon's method. The animals were weighed daily, on a scale accurate to 1 lb., on 3 days before and after calving and at weekly intervals throughout the lactation. Details of the breed type of the experimental animals, calving dates, and body weights at calving and at 252 days after calving, are shown in Table 1.

RESULTS

The production of the animals in a maximum of the first 252 days after calving has been considered, since after this period differences between animals due to pregnancy effects would probably have influenced results. Table 2 shows the milk, butterfat, solids-not-fat,

TABLE 1. BREED TYPE, CALVING DATE, AGE AT CALVING AND BODY WEIGHTS AT CALVING AND AT 252 DAYS AFTER CALVING

Twin No.	Breed	Calving Date	Age at Calving		Body Weight (lb.)	
			yrs.	days	At Calving	At 252 days after calving
T29	Grade Jersey	27/10/51	2	93	704	784
T30	,, ,,	14/9/51	2	50	626	731
T43	,, ,,	3/8/51	2	3	658	817
T44	,, ,,	11/8/51	2	11	648	844
T81	Jersey/Ayrshire	17/7/51	2	56	776	930
T82	,, ,,	23/7/51	2	67	776	977
T25	Jersey/Jersey Shorthorn	31/7/51	3	57	874	1060
T26	,, ,,	22/7/51	3	48	819	940
T49	Grade Jersey	1/8/51	2	329	697	792
T50	,, ,,	20/7/51	2	317	744	793
T71	,, ,,	1/8/51	2	322	697	762
T72	,, ,,	5/8/51	2	326	625	743
T89	Jersey/Ayrshire	22/7/51	2	356	768	904
T90	,, ,,	16/7/51	2	350	757	913
T15	Jersey/Red Poll	30/7/51	3	344	957	1080
T16	,, ,, ,,	6/8/51	3	351	890	1005
T17	Jersey/Jersey Polled Angus	9/8/51	4	312	903	958
T18	,, ,,	13/8/51	4	316	927	976
T53	Grade Jersey	10/8/51	4	333	855	973
T54	,, ,,	14/7/51	4	306	880	986

total protein, and lactose productions of the cows for the 252 day lactations.

It can be seen from Table 2 that there are in some cases wide differences between members of a set of twins in production. The average within-set differences were 780.6 lb., 24.9 lb., 67.7 lb., 25.4 lb., and 41.8 lb. for total milk, butterfat, solids-not-fat, total protein, and lactose productions, respectively. The differences between the highest- and lowest-producing sets were 5,733 lb. milk, 262 lb. butterfat, 495 lb. solids-not-fat, 178 lb. total protein, and 276 lb. lactose.

TABLE 2. MILK, BUTTERFAT, SOLIDS-NOT-FAT, TOTAL PROTEIN, AND LACTOSE PRODUCTION FOR THE COMPLETE LACTATION

Twin No.	Milk		Butterfat		Solids-not-fat		Total Protein		Lactose		Days of Lactation
	lb.	diff.	lb.	diff.	lb.	diff.	lb.	diff.	lb.	diff.	
T29	4537	509	166	2	431	48	167	20	231	36	212
T30	5046		168		479		187		267		252
T43	3768	1270	186	59	348	126	141	52	186	75	252
T44	2498		127		222		89		111		219
T81	3387	901	147	36	305	79	125	33	166	53	252
T82	2486		111		226		92		113		226
T25	4463	1210	258	47	462	85	193	35	240	47	252
T26	5673		305		547		228		287		252
T49	6897	53	389	4	650	7	273	4	323	4	252
T50	6950		393		657		277		327		252
T71	8276	301	386	14	755	32	287	15	421	26	252
T72	7975		372		723		272		395		252
T89	4911	1183	213	43	453	107	173	36	244	62	252
T90	6094		256		560		209		306		252
T15	6808	779	340	14	654	59	276	17	335	34	252
T16	7587		354		713		293		369		252
T17	8218	902	257	28	732	56	278	17	397	37	252
T18	9120		285		783		295		434		252
T53	6301	698	274	2	634	78	257	25	328	44	252
T54	5603		272		556		232		284		252

Table 3 shows details of the average composition of the milks of the cows for the 252 day lactations.

The average within-set differences were 0.18%, 0.14%, 0.09%, and 0.16% for butterfat, solids-not-fat, total protein, and lactose contents respectively. The differences between the highest and lowest sets were 2.52%, 1.23%, 0.80% and 0.51% respectively.

A difficulty encountered in production experiments is the evaluation of a cow's "total" production. This difficulty arises from the fact that growth, weight changes in mature cows, and milk yield, are forms of production which are not very easily brought to a common unit so that they can be compared or summed. However, as both milk yield and

change in live weight are manifestations of changes in energy, it is suitable to express both in some unit of energy. Production may be expressed in terms of fat-corrected-milk (F.C.M.) yield which in turn may be expressed in calories, and weight change can also be expressed in calories sufficiently accurately for the purpose of this study. Within-set differences in production may sometimes be accounted for by differences in body-weight changes over the lactation period. The body

TABLE 3. AVERAGE MILK COMPOSITION FOR 252 DAYS MAXIMUM LACTION PERIOD

Twin No.	Butterfat		Solids-not-fat		Total Protein		Lactose	
	%	diff.	%	diff.	%	diff.	%	diff.
T29	3.67	0.34	9.51	0.02	3.68	0.03	5.10	0.20
T30	3.33		9.49		3.71		5.30	
T43	4.93	0.14	9.23	0.33	3.73	0.15	4.93	0.49
T44	5.07		8.90		3.58		4.44	
T81	4.35	0.13	9.01	0.07	3.69	0.01	4.90	0.34
T82	4.48		9.08		3.68		4.56	
T25	5.54	0.16	9.92	0.27	4.14	0.12	5.15	0.09
T26	5.38		9.65		4.02		5.06	
T49	5.64	0.02	9.43	0.02	3.97	0.03	4.69	0.01
T50	5.66		9.45		4.00		4.70	
T71	4.66	—	9.12	0.05	3.47	0.05	5.09	0.13
T72	4.66		9.07		3.41		4.96	
T89	4.33	0.12	9.22	0.02	3.53	0.11	4.97	0.06
T90	4.21		9.20		3.42		5.03	
T15	4.99	0.32	9.61	0.22	4.06	0.20	4.92	0.05
T16	4.67		9.39		3.86		4.87	
T17	3.13	0.01	8.90	0.27	3.38	0.15	4.84	0.08
T18	3.12		8.63		3.23		4.76	
T53	4.35	0.51	10.07	0.14	4.07	0.07	5.21	0.17
T54	4.86		9.93		4.14		5.04	

weight changes are shown in Figure 1 and in the "total" productions of the twins, Table 4. In this table, body-weight changes over the lactation period are shown, and the F.C.M. yield and body-weight change are expressed in terms of calories using 340 cal./lb. F.C.M. and 3,409 cal./lb. live-weight gain (Bonnier *et al.* 1948) as conversion factors. Finally, in the last major column the estimated "total" production in terms of calories is shown.

The average within-set differences were 685.3 lb. (232.2×10^3 cal.), 31.9 lb. (108×10^3 cal.), and 202.5×10^3 cal. for F.C.M. yield body-weight change, and "total" production respectively. The differences between the highest and lowest sets were 5,823 lb. F.C.M., 126 lb. body weight, and $1,670 \times 10^3$ cal. "total" energy production.

Considering Table 4 it can be seen that in some cases wide within-set differences in F.C.M. milk yield expressed in calories were associated with fairly wide within-set differences in body weight change

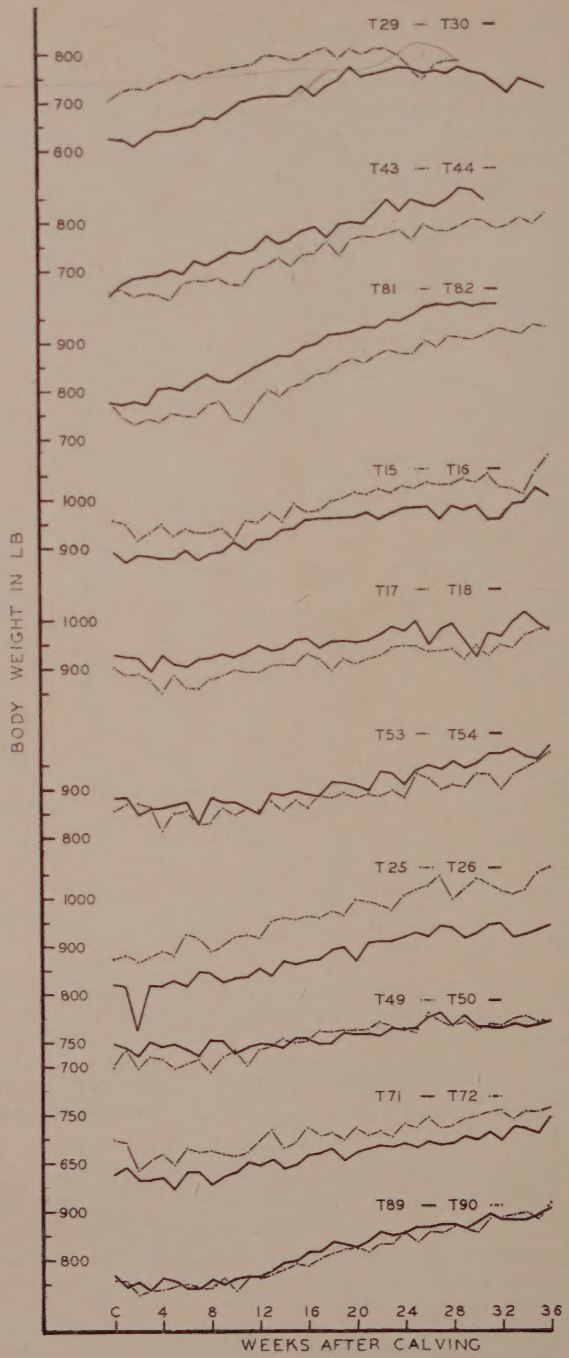


Fig. 1.—Bodyweight changes of the twin sets throughout lactation.

TABLE 4. YIELD OF F.C.M., BODY WEIGHT CHANGES AND "TOTAL" PRODUCTION

Twin No.	F.C.M. Production				Body-weight Changes				"Total" Production	
	lb.	diff.	cal. x 10^3	diff.	lb.	diff.	cal. x 10^3	diff.	cal. x 10^3	diff.
T29	4305	233	1463	80	80	25	273	85	1736	165
T30	4538		1543		105		358		1901	
T43	4297	1393	1461	474	159	37	542	126	2003	348
T44	2904		987		196		668		1655	
T81	3560	896	1201	295	164	37	559	126	1769	178
T82	2264		906		201		685		1591	
T25	5655	1139	1923	404	186	65	634	222	2557	182
T26	6844		2327		121		412		2739	
T49	8594	81	2922	28	95	46	324	157	3246	129
T50	8675		2950		49		167		3117	
T71	9100	330	3094	112	65	53	221	181	3316	68
T72	8770		2982		118		402		3384	
T89	5159	1119	1754	381	136	20	464	68	2218	448
T90	6278		2135		156		532		2666	
T15	7823	522	2660	177	133	18	453	61	3113	116
T16	8345		2837		115		392		3229	
T17	7142	781	2428	266	55	6	187	20	2616	245
T18	7923		2694		49		167		2861	
T53	6630	309	2254	105	118	12	402	41	2656	146
T54	6321		2149		106		361		2510	

expressed as calories. This applies especially to sets T43-44, T81-82, T25-26. However, in other cases the within-set differences in body weight change was wider than the within-set difference in production, viz., T29-30, T71-72, T49-50. The remaining sets show that within-set differences in production of varying magnitude were not associated with within-set differences in body-weight change of corresponding magnitude. It thus appears that body-weight changes differed in their effect on within-set differences in milk, fat, and "total" energy production.

Relationships between Constituents of Milk

A study was made of the relationship between the fat content of the milk and other milk constituents. Linear regression equations were derived as follows:—

Fat % (X) and S.N.F. % (Y) $Y = 8.44 + 0.199\,X$ (not significant)

——— (X) and Total Protein % (Y) $Y = 2.66 + 0.237\,X$ (5% level of significance)

——— (X) and Lactose % (Y) $Y = 5.57 - 0.141\,X$ (1% level of significance)

Graphs of the above regressions appear in Fig. 2. As Hancock (1950) has shown with fat % and casein %, the individual points are

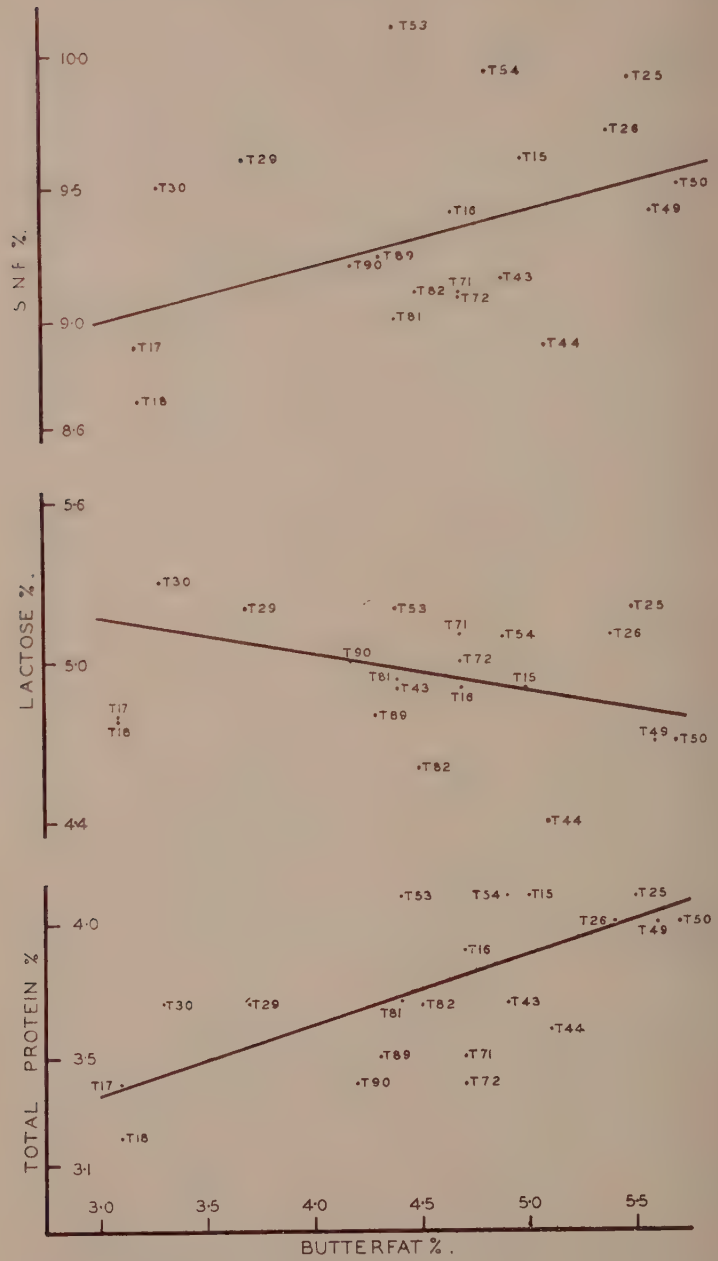


Fig. 2.—Relationships between constituents of milk; whole lactation averages.
Y (S.N.F.%) = 8.44 + 0.199 X (fat %).
Y (Total protein %) = 2.65 + 0.237 X (fat %).
Y (Lactose %) = 5.57 — 0.141 X (fat %).

scattered widely about the regression lines and the points for each twin set lie fairly close to each other.

The points do not follow the regression line very closely, indicating that the correlation coefficient would be small in each case. However, the fact that twin sisters have similar values suggests that there is an independent genetical variation in these characters apart from the genetical relationships between them. A similar conclusion based on much more data has been reached by Larson *et al.* (1949) and Bonnier and Hansson (1946).

Relative Value of Twins for Experimental Purposes

A comparison of the usefulness of twins with that of cows chosen at random entails an estimation of the within- and between-set differences of twins. The former provides an estimate of the random variations of individuals of the same genotype while the latter provides an estimate of the variations between animals of different genotypes. Thus the within-set and between-set variance derived from an analysis of variance provide the two estimates needed.

For production characters particularly, allowance has to be made for the effect of age, as failure to do this would cause large between-set differences. The method used was to take out, in the analysis of variance, the variance due to age groups, and to derive the efficiency value from the between-twin-pair-within-age-group variance and the within-set-within-age-group variance by the method proposed by Dick and Whittle (1951).

Table 5 shows the three mean squares and the efficiency values derived from the appropriate components of variance for production characters. Table 6 shows the components of variance of the three sources of variation expressed as percentages of the total variances.

When the efficiency values were calculated without eliminating the variance due to different age groups, the efficiency values for production characters were 9.4, 16.5, 10.2, 10.9, and 11.3 for milk, butterfat, solids-not-fat, total protein, and lactose production respectively.

TABLE 5. TWIN EFFICIENCY VALUES FOR PRODUCTION CHARACTERS

Characteristic	Between-set Mean Square		Within-set Mean Square	Twin Efficiency Value
	Between Age Groups	Between Sets Within Age Groups		
Total energy prod. cal. x 10^3	1808665	193605	26495	3.2
F.C.M. yield	19316904	3154926	327841	4.3
Milk yield	14898437	3845972	380655	4.6
Butterfat yield	39100.6	6025.8	501.8	5.5
S.N.F. yield	132581.3	25128.5	2843.5	3.9
Total protein yield	21423.0	3277.0	408.3	3.5
Lactose yield	36989.6	8719.8	767.5	5.2

TABLE 6. SOURCE OF VARIATION EXPRESSED AS PERCENTAGE OF THE TOTAL VARIANCE

Source of Variation	Total Energy Prodn.	F.C.M. Yield	Milk Yield	B/Fat Yield	S.N.F. Yield	Total Protein Yield	Lactose Yield
Between age groups	77.6	70	59.6	71.9	66.5	70.9	62.0
B. sets within age groups	17.0	24	33.1	23.9	26.6	22.5	31.9
Within sets	5.4	6	7.3	4.4	6.9	6.6	6.1

Table 7 and 8 show the twin efficiency values and components of variance expressed as percentages of the total variance for milk composition characteristics. Here there was no attempt made to subdivide the between-set variance, since it was considered that age effects on milk composition would not be very great.

TABLE 7. TWIN EFFICIENCY VALUE FOR MILK COMPOSITION CHARACTERISTICS

Characteristic	Between-set Mean Square	Within-set Mean Square	Twin Efficiency Value
Butterfat %	1.2482	0.0262	23.3
Solids-not-fat %	0.2311	0.0166	8.0
Total protein %	0.1597	0.0061	12.6
Lactose %	0.0744	0.0226	1.2

TABLE 8. SOURCE OF VARIATION EXPRESSED AS PERCENTAGE OF THE TOTAL VARIANCE FOR MILK COMPOSITION CHARACTERS

Source of Variation	Butterfat %	Solids-not-fat %	Total Protein %	Lactose %
Between sets	95.9	88.8	92.6	54.5
Within sets	4.1	11.2	7.4	45.5

Transformation of the raw percentages into angles did not bring about any differences in the analysis when each was compared with the analysis on the raw data. All the results presented were therefore derived from the raw percentage figures.

These efficiency values for milk composition characters, except in the case of lactose content, are much higher than for production characters and these latter are much lower than those estimates derived by Hancock (1950). It is not clear why the efficiency values from these two experiments should differ, especially for production characters.

It must be remembered that these two experiments represent two different samples of the population. As shown in Table 10 the values derived from other experiments at this Institute using two-year-old animals only are, for milk and butterfat production, of the same order as the values obtained in this paper.

The between-set and within-set coefficients of variation shown in Table 9 perhaps explain more clearly than do the respective mean squares the differences in the efficiency values obtained for the various characteristics.

Repeatability estimates and also the 80% confidence limits for the efficiency values and the repeatability estimates are included in the table. These limits stress the relative inaccuracies and range of values possible, particularly in regard to the twin efficiency values. The limits proposed help to explain the differences in these efficiency values found with different experiments and by different workers.

TABLE 9. EFFICIENCY AND REPEATABILITY ESTIMATES WITH 80% CONFIDENCE LIMITS AND THE BETWEEN AND WITHIN SETS COEFFICIENTS OF VARIATION

Characteristic	Efficiency Value	Limits	Repeatability	Limits	Between Set Coefficient of Variation	Within Set Coefficient of Variation
Total energy prodtn.	3.2	0.99–10.24	0.75	0.50–0.91	5.7	3.2
F.C.M. yield	4.3	1.46–13.65	0.81	0.59–0.93	9.5	4.6
Milk yield	4.6	1.55–14.35	0.82	0.64–0.94	11.3	5.3
Butterfat yield	5.5	1.94–17.15	0.84	0.66–0.95	10.0	4.3
S.N.F. yield	3.9	1.30–12.50	0.79	0.56–0.93	9.7	4.9
T. protein yield	3.5	1.13–11.31	0.77	0.53–0.92	8.7	4.6
Lactose yield	5.2	1.81–16.20	0.83	0.64–0.94	10.9	4.8
Butterfat %	23.3	9.63–57.15	0.95	0.91–0.99	8.6	1.8
S.N.F. %	8.0	3.10–19.89	0.88	0.76–0.95	1.9	0.7
T. protein %	12.6	5.07–31.18	0.92	0.84–0.97	3.7	1.0
Lactose %	1.2	0.20– 3.48	0.54	0.17–0.78	1.6	1.5

It can be seen from this table that the high efficiency value for butterfat % was due to a small within-set variance relative to the large between-set variance. Other characters with small efficiency values have small between-set variances accompanied by relatively large within-set variances. This is particularly evident in the case of lactose percentage.

Efficiency values based on a few sets of twins are subject to wide sampling errors. Previous work at The Dairy Research Institute (N.Z.) with identical twins enabled efficiency values to be derived from other samples of twins. These were taken from a paper by Flux (1950) and Flux and Patchell (1954). The characters chosen were those in which the nutritional treatments showed no significant effect and the data were thus used as uniformity data. Only two-year-old animals were used. The efficiency values are listed in Table 10.

TABLE 10. TWIN EFFICIENCY VALUES

Character	No. of Twin Sets	Efficiency Value	Source of Information
Butterfat%	6	28.5	Flux (1950)
Total protein %	6	14.6	
Lactose %	5	6.6	
Milk production	7	6.9	Flux and Patchell (1954)
Butterfat production	7	6.3	
Butterfat %	7	25.4	
Total protein %	7	23.8	

These values are similar to those pertaining to the data described in this paper. Lactose per cent was higher for the 1950 data than that derived from the present trial. Lactose determinations were made twice weekly during the 1949–50 season whereas they were determined once a fortnight during the 1951/52 season. It is not known whether the less-frequent determination of lactose had any influence on the resultant low efficiency value. It has been shown by Bonnier *et al.* (1948) that with lactose percentage a large part of the variation is associated with the interaction and error terms in the analysis of variance.

It is evident that, owing to the relatively small sample of twins used in each case, between-set and within-set variances are subject to large sampling errors, and the values are therefore to be regarded as rough guides to detect which of several characters may be usefully studied with the use of identical twins, or which could be studied with ordinary unrelated animals.

In an actual experiment, the error term would include the interaction of inheritance by treatment (or environment) portion of the variance and if such interactions are significantly large the statistical efficiency would be lower than that indicated by uniformity data. Such non-linear interactions between genotype and environment occur (Bonnier *et al.* 1948) and the number of twin pairs necessary for an experiment is likely to be much greater than indicated by data from uniformity trials since the error mean square would be increased by the interaction.

Apart from these theoretical considerations, real practical difficulties exist with identical twins; these have been discussed at some length by Hancock (1950).

THE VALUE OF TWINS FOR GENETIC STUDIES

Heritability estimates, particularly for milk and butterfat production and butterfat yield, have been reported by a number of workers, e.g., Lush and Schultz (1936), Lush *et al.* (1941), Ward and Campbell (1940), Laben and Herman (1950) and Johansson (1950). These are estimates of heritability in the narrow sense, dealing only with the additive genetic variance. Heritability in the broad sense includes dominance and epistatic genetic variances as well as the additive portion. The term heritability is also used in connection with identical-twin experiments to describe the proportion of the total variance in the

analysis of variance which is due to between-set or hereditary differences. These have been calculated by Bonnier *et al.* (1948) and Hancock (1950–51), and those calculated in this paper are listed in Tables 5 and 7. However, it should be pointed out that such values tend to be overestimated with twin material. The variance between members of the same set of twins, or the within-set variance, is environmental, whereas the variance between two unrelated individuals chosen at random from the population contains both genetic and environmental variations.

With twin data we use the between-set component of variance (P) and the sum of this variance component and the within-set variation (P + Q) to estimate the heritability P/(P + Q). However, as pointed out by Johansson (1950) such estimates are really repeatability estimates, and the within-set variance probably under-estimates the environmental component. Twins tend to be rather more similar than two random unrelated animals because of their common environment, particularly pre-natal and to a less extent post-natal. Thus the environmental component is underestimated and the heritability estimate overestimated. The variance attributed to heredity in twin experiments includes additive, dominance, and epistatic deviations, and, in addition, a source of variation associated with the effect of common environment.

The repeatability estimates for the various characters studied in this paper are listed in Table 9. In spite of the fact that these values are probably overestimated, the gap between these and the estimates of heritability (in the narrow sense) of 30% to 40% for milk and butterfat production observed in the literature, is very large. In order to decide what type of breeding plan should be followed in improving or maintaining at a high level the production of herds of dairy cattle, it would be of great value to know the size of the contribution which the common environment and the effect of dominance and epistasis have on twin heritability estimates. In other words what contribution do these three sources make to the difference between heritability estimates derived from monozygous twin data and those derived by the usual methods. It may be that the strictly controlled conditions and the accuracy of measurement with twin material is a factor also in contributing to high heritability values. The use of fraternal twins would help to solve the problem of how much the common environment is affecting the values, provided fraternal and monozygous twins were run together under uniform conditions. However, as Lush (1949) has pointed out, the method becomes only reasonably accurate if the effect of dominance and epistasis is small. How are we to find out whether dominance and epistasis are contributing a large amount or not? One approach would be to observe the performance of fraternal and identical twins under the same conditions. At the same time it would be interesting to study the results obtained by running at the same time several groups of daughters and dams being used to progeny-test different bulls. Accurate and strictly controlled experimental conditions may increase the additive genetic fraction above that obtained in the past by such dam–daughter comparisons under less strictly controlled conditions. It is important to know (at our present state of knowledge in animal breeding) the contribution of these factors since, when additive genetic variation has been much reduced as a result of selection, the remaining genetic variance would depend upon epistasis and dominance. At that stage, breeding plans might need to be changed radically.

Acknowledgements

The author wishes to acknowledge the work of the staff of the Chemistry Laboratory of this Institute, under Dr. F. H. McDowall, who carried out the milk analyses, and the work of Mr. D. Collis and the farm staff who milked, and otherwise looked after, the animals.

Very grateful thanks and acknowledgement are due to Dr. J. H. Darwin, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, for the calculation of the confidence limits of the variance ratios.

References

Bonnier, G.; Hansson, A. 1946: *Acta agric. suec. 2:* 171.

Bonnier, G.; Hansson, A.; Skjervold, H. 1948: *Ibid. 3:* 1.

Dick, I. D.; Whittle, P. 1951: *N.Z. J. Sci. Tech. B33(3):* 145.

Flux, D. S. 1950: *J. agric. Sci. 40:* 177.

Flux, D. S.; Patchell, M. R. 1954: *J. agric. Sci. 45:* 246.

Hancock, J. 1950: *N.Z. J. Sci. Tech. A31 (5):* 23.

————1951: *Annu. Rep. Anim. Res. Div. N.Z. Dep. Agric.* p. 15.

Johansson, I. 1950: *Anim. Breed. Abstr. 18:* 1.

Larson, E. L.; Platon, J. B.; Thome, K. E.; Hansson, A. 1949: *13th Int. Dairy Congr. 1:* Sec. I and VI, p. 377.

Laben, R. C.; Herman, H. A. 1950: *Mo. agric. Exp. Sta. Res. Bull. 459.*

Lush, J. L. 1949: *Proc. 8th int. Congr. Genet.* p. 356.

Lush, J. L.; Schultz, F. N. 1936: *J. Dairy Sci. 19:* 429.

Lush, J. L.; Norton, H. W.; Arnold, F. 1941: *J. Dairy Sci. 24:* 695.

McDowell, A. K. R. 1941: *J. Dairy Res. 12:* 131.

Ward, A. H.; Campbell, J. T. 1940: *Emp. J. exp. Agric. 8:* 249.

A NOTE ON AN OUTBREAK OF *Verticillium* WILT IN A NELSON HOP GARDEN

By T. Christie, Cawthron Institute, Nelson

(Received for publication, 9 December 1955)

Summary

An account is given of the finding of hop plants in a garden at Tadmor infected by *Verticillium albo-atrum* Reinke and Berth.

Symptoms are described and measures taken to control the outbreak are outlined.

During the 1952-53 season, hop plants of the Californian variety in a one-year-old garden in the Tadmor district were found with wilting and dead bines. The total area of the hop garden was approximately four acres. Plants with varying symptoms of infection were found only in the southern half of the garden where potatoes had been planted one year previously. One hundred and forty-five plants in this area had symptoms of infection. Infected plants were scattered but tended to occur in groups, with the greatest concentration in the south-western corner of the garden. It was in this region that plants with the most marked symptoms were present.

Symptoms varied from plant to plant. Mild symptoms were an inter-veinal yellowing of the basal leaves of bines, with black streaks on the surfaces of the leaves. On more severely affected bines the margins of the leaves were black and curled upwards with a yellowing of the major areas of the leaves. The most marked symptoms were the wilting and death of bines with the destruction of all leaves. On some bines these dead leaves were still attached, but they fell at a touch.

The wood cylinders, of affected plants, save those with mild symptoms, were found to be stained a brown colour. This discolouration extended varying distances up the bines, from a few inches above soil level to a height of six feet in plants with severe symptoms. Some bines were discoloured on one side only of the wood cylinder. With all affected plants the bines were firmly attached to the rootstocks and there was no basal swelling of the bines.

Isolations from dead leaves and from the stained wood cylinders consistently yielded a fungus identified in culture as *Verticillium albo-atrum* Reinke and Berth. This identification was confirmed by Mr. R. M. Brien of the Plant Diseases Division, Auckland.

Between the rows of hop plants a few rogue potato plants were found. From one of these plants, which had yellow basal leaves and a brown streak in the vascular cylinder, *Verticillium dahliae* Kleb. was isolated. No isolations of *V. albo-atrum* were obtained from the potato plants examined.

Although there is no direct evidence that *V. albo-atrum* was introduced into the hop garden with the previously planted potato crop, the occurrence of *Verticillium* infection only in that portion of the garden which was planted in potatoes suggests that the disease was brought in with the potato plants. The isolation of *V. dahliae* from a rogue potato plant further suggests that the two species of the fungus were present with the potatoes.

Recommendations were made by the Hop Research Committee for the destruction of that portion of the hop garden where infected plants were growing. These involved the lifting and burning of all hop plants in the area, the removal and sterilization of posts, and the sowing of the area to grass pasture. These recommendations were carried into effect by the grower in collaboration with officers of the Department of Agriculture.

During the two following seasons the remaining portion of the hop garden has been examined each year for evidence of *Verticillium* infection but no symptoms of infection have been found.

Tests were subsequently made of the pathogenicity of the strain of *V. albo-atrum* isolated from hop plants and that of *V. dahliae* from a potato plant to hop plants of the Californian and Fuggle varieties. The results of these tests are reported in a further communication.

PATHOGENICITY TESTS WITH SPECIES OF *Verticillium*

By T. Christie, Cawthron Institute, Nelson

(Received for publication, 9 December 1955)

Summary

Tests have been made of the pathogenicity of strains of *Verticillium dahliae* and *V. albo-atrum* to tomato, potato, and hop plants.

Differences were found in the ability of the tested strains to produce symptoms of infection.

Introduction

For some years *Verticillium dahliae* Kleb. has been the cause of a serious wilt disease of tobacco in the Motueka district. The same fungus is responsible for a wilt disease of tomato plants in Nelson. In January 1953, hop plants of the Californian variety in a Tadmor hop garden, which had previously been planted to potatoes, were found with wilting and dead bines. Isolations from diseased plants consistently yielded *Verticillium albo-atrum* Reinke and Berth. From a rogue potato plant growing between the rows of hop plants *V. dahliae* was isolated. Inoculation trials, which are reported below, were begun to determine what differences, if any, existed in the ability of these species of *Verticillium* to infect hop, tomato, and potato plants. For comparison with the local hop strain of *albo-atrum* a culture was obtained from the East Malling Research Station, England, of the strain of the same fungus which is responsible for the "fluctuating" wilt disease of hop plants in England.

Experimental

Sterilized soil in pots was inoculated by means of agar squares with tobacco and tomato strains of *V. dahliae* and the hop strain of *V. albo-atrum*. In each series there were six pots. A similar number of pots was left uninoculated as controls. Tomato plants of the Potentate variety were planted in these pots, three plants in each series being root wounded and the appropriate strain of the fungus applied to the wounded tissue, two were root wounded only, and one was unwounded.

Foliar symptoms of infection appeared on all plants growing in soil inoculated with the tomato strain of *V. dahliae* and the hop strain of *V. albo-atrum*. The wood cylinders of these plants were stained and the fungus was isolated from all plants. Three plants, those root wounded with the fungus applied to the wounded tissue, growing in soil inoculated with the tobacco strain of *V. dahliae* did not have foliar symptoms, but some staining of the wood cylinder was present and the fungus was isolated from this tissue. The three remaining plants in this series and the six control plants showed no symptoms and no isolations of the fungus were obtained from these plants.

Soil in similar numbers of pots received strains of *V. dahliae* from tobacco and potato plants and the hop strain of *V. albo-atrum*. Potato tubers of the Red Dakota variety were planted to these pots, and as with the tomato plants the appropriate strain of the fungus was applied

at the time of planting. As before, six tubers were planted in uninoculated soil as controls.

Plants growing in soil inoculated with the hop strain of *V. albo-atrum* had marked foliar symptoms, as did also those in soil inoculated with the potato strain of *V. dahliae*. Where the fungus was applied to the cut surfaces of the tubers before planting, symptoms appeared early and were well defined. The wood cylinders of all these plants were stained. From all plants in soil inoculated with the hop strain of *V. albo-atrum* the fungus was recovered and *V. dahliae* was isolated from the plants in soil inoculated with the potato strain of this species. No symptoms appeared on those plants inoculated with the tobacco strain of *V. dahliae*, nor was there any staining of the wood cylinders. No isolations were obtained from these plants. The control plants likewise showed no symptoms nor any staining of the wood cylinders.

Sterilized soil in twelve pots was inoculated with the local hop strain of *V. albo-atrum*, and a similar number of pots received the English "fluctuating" strain of the same fungus. Soil in six pots each was inoculated with the potato, tobacco, and tomato strains of *V. dahliae*.

Hop cuttings of the Californian variety were planted in six pots inoculated with the local strain of *V. albo-atrum* and in six pots inoculated with the English strain. The remaining six pots in each of these series were planted with cuttings of the Fuggle variety. All other pots were planted with Californian cuttings. Nine Californian and three Fuggle cuttings were planted in uninoculated soil as control plants.

Plants were grown for one season only. Of the six Fuggle plants in soil inoculated with the local strain of *V. albo-atrum* one died and a marked discolouration of the wood cylinder was found in two plants. These had foliar symptoms. From these three plants the fungus was isolated. Of the remaining three plants, two were free from symptoms with no discolouration of the wood cylinder, and one, although slight foliar symptoms were present, had no discolouration of the wood cylinder. No isolations of the fungus were obtained from these plants.

Of the six Fuggle plants in soil inoculated with the English strain, two plants died, and two plants, both with foliar symptoms, showed a marked discolouration of the wood cylinder. The fungus was isolated from these four plants. The remaining two plants were free from foliar symptoms, no staining of the wood cylinder was found, and no isolations of the fungus were obtained.

Of the six Californian plants inoculated with the local hop strain, a light discolouration of the wood cylinder was found in five plants, four of these having foliar symptoms. The fungus was recovered from only two of these plants. The remaining plant had no leaf symptoms, no discolouration of the wood cylinder was found, and no isolation of the fungus were made.

Of the six Californian plants inoculated with the English strain, all plants were free of symptoms and no discolouration of the wood cylinder was found in four plants. Two plants had a slight discolouration of the wood cylinder. No isolations of the fungus were obtained from any of the six plants.

No leaf symptoms and no discolouration of the wood cylinder were present in the Californian plants growing in soil inoculated with the tobacco, tomato, and potato strains of *V. dahliae*. No isolations of the fungus were obtained from these plants. The control plants, both of the Fuggle and Californian varieties, were comparable with these plants.

CONCLUSIONS

Under the conditions of these tests it would appear that there are differences in the pathogenicity of strains of *Verticillium* towards tomato, potato, and hop plants. The local hop strain of *V. albo-atrum* was as pathogenic to tomato plants as the tomato strain of *V. dahliae*. No symptoms of infection appeared on tomato plants growing in soil inoculated with the tobacco strain of *V. dahliae*, but the fungus was recovered from three plants which were wounded before planting and the fungus applied to the wounded tissue.

The local hop strain of *V. albo-atrum* was markedly pathogenic to the potato plants tested, as was also the strain of *V. dahliae* isolated from a potato plant. The tobacco strain of *V. dahliae* produced no symptoms of infection on potato plants.

A comparison of the local hop strain of *V. albo-atrum* with the English "fluctuating" strain of the same fungus revealed differences between the two when tested against hop plants of the Californian and Fuggle varieties. The local strain produced more marked symptoms of infection on plants of the Californian variety than did the English strain. However, the English strain was more infective to Fuggle plants than to Californian plants. Both the local strain and the English strain infected Fuggle plants more severely than Californian plants.

There was no indication that the tomato, tobacco, and potato strains of *V. dahliae* were capable of infecting hop plants of the Californian variety.

ACKNOWLEDGEMENT

Thanks are due to Dr. R. V. Harris of the East Malling Research Station, England, for kindly providing a culture of the strain of *V. albo-atrum* which causes the "fluctuating" wilt disease of hops.

THE USE OF DRIED BUTTERMILK AS A COMPLETE REPLACEMENT OF WHOLE MILK FOR THE REARING OF YOUNG DAIRY CALVES

(Received for publication, 14 September 1955)

By D. S. Flux and M. R. Patchell, The Dairy Research Institute (N.Z.), Palmerston North

Summary

Sixteen spring-born Jersey calves were divided into two groups, and after three days feeding with colostrum one group received whole milk at the rate of 12½% body weight per day, whilst the other group received reconstituted buttermilk (made up of 1.8 lb. dried buttermilk to 8.2. lb. water) also fed at the same rate. The difference in weight gains from 1 to 8 weeks of 1.1 lb. per week in favour of the calves fed whole milk was not statistically significant.

Introduction

Previous trials at the Institute have been concerned with the use of reconstituted buttermilk fed to calves after the first month on whole milk (Flux and Patchell 1955) and with the possibility of replacing part of the dried buttermilk with cheaper cereals and feeding the mixtures in the form of a gruel or a dry calf meal (Patchell 1955).

These trials showed that dried buttermilk, either reconstituted or with part of the buttermilk replaced by cereals, could be used for the rearing of Jersey calves with varying degrees of success, and it was thought desirable to determine the age at which young calves could be started on dried buttermilk. The earlier in the calf's life this can take place the greater the saving in whole milk will be.

Experimental Materials and Methods

Sixteen spring-born Jersey calves from the Institute's herd were used in a covariance type of experiment with 8 calves per treatment group. All calves were fed colostrum for the first three days after birth. Those in one group, the controls, received thereafter whole milk fed at the rate of 12½% of body weight per day whereas those in the other group were fed reconstituted buttermilk at the same rate.

The dried buttermilk was reconstituted by mixing 1.8 lb. of dried buttermilk with 8.2 lb. of warm water, giving a mix with approximately the same energy content as the whole milk.

The calves were fed twice daily, at the morning and evening milkings. At all times they were rotationally grazed on good-quality pasture. Once each week the calves were weighed on a scale accurate to 1 lb. and throughout the trial a detailed record was kept of calf health.

Results

The weight gains from one to eight weeks of age, when the experiment concluded, were analysed by an analysis of variance as shown in Table 1.

TABLE 1. ANALYSIS OF VARIANCE OF WEIGHT GAINS
(One to eight weeks)

Source	d.f.	S.S.	M.S.	F.
Total	15	2344		
Between treatments	1	240	240	1.60 N.S.
Remainder		2104	150	

N.S. = Not significant.

The standard deviation was 12.2 lb.; the general mean was 44 lb.; and the resultant coefficient of error variance was 27.7%.

Covariance analysis was tried with the initial weight as the independent variable but the regression was found to be non-significant.

The average weight gains for the control calves from one to eight weeks of age was 47.9 lb., or 6.8 lb. per week, while for the calves fed reconstituted buttermilk the corresponding figures were 40.1 and 5.7 lb. per week. The difference of 1.1 lb. per week was not significant.

The growth rates of calves in the two groups are shown in Fig. 1. Some trouble was experienced with both white and blood scours during the first three weeks, calves in both groups being affected. It is probable that the infection spread from twin calves brought into the shed at about

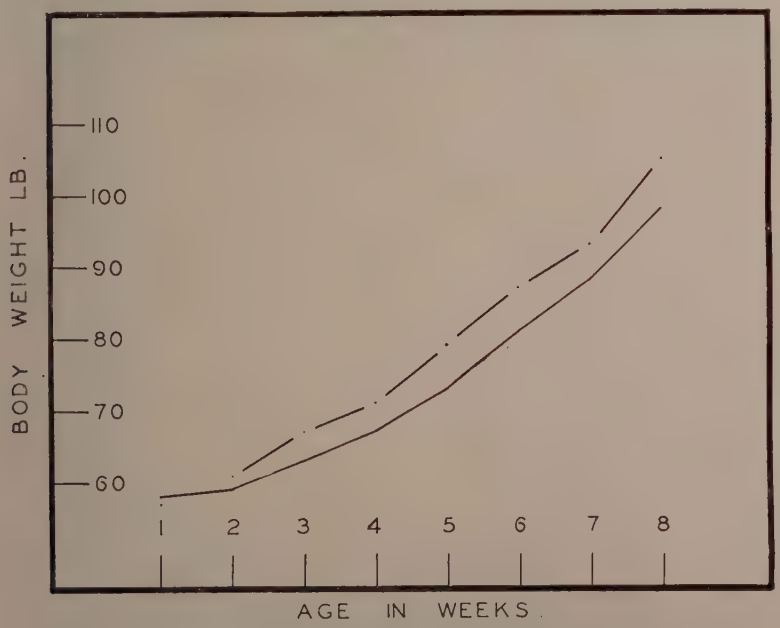


Fig. 1.—Average growth curves for the control and experimental groups.
Control calves — . — . Calves fed buttermilk ————

this time. As a general preventative, a treatment with sulphamethazine was given to all calves for four days from 11 to 15 August. However, scouring was still prevalent in the buttermilk group and on 20 September, when most of the calves were three weeks old, a daily dose of vitamins A and D was started for each calf being fed buttermilk. This dose of 1 capsule per day was given by means of Adexolin tablets produced by Glaxo Laboratories; each capsule contained 4,000 I.U. of vitamin A and 400 I.U. of vitamin D.

Subsequent to this daily treatment of the buttermilk calves there was one case of scouring in each group.

Discussion

The trial described in this paper showed that young dairy calves could be reared sucessfully by feeding colostrum for the first three days and thereafter reconstituted buttermilk at the rate of 12½% body weight. Although scouring was prevalent during the first three weeks, this applied initially to both groups. After treatment with sulphamethazine scouring ceased in the control goup but it was not until the buttermilk calves had begun to receive a daily allowance of vitamin A and D that scouring ceased in this group. Although the reconstituted buttermilk would be low in these fat-soluble vitamins, it is not clear whether the scouring ceased because of the supplements or because the calves became more resistant as they became older. It is usual to find more trouble with scouring in younger calves.

The experiment showed that calves may be reared without the use of whole or separated milk. From a practical point of view a slightly slower growth rate of calves fed reconstituted buttermilk would be of little importance if rearing costs were lower than they would be if whole milk was used.

References

Flux, D. S.; Patchell, M. R. 1956: *N.Z. J. Sci. Tech. A37:* 451-7.
Patchell, M. R. 1956: *N.Z. J. Sci. Tech. A37:* 538-41.

THE EFFECT OF AUREOMYCIN SUPPLEMENT ON THE GROWTH AND HEALTH OF YOUNG CALVES

By M. R. Patchell, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 14 September 1955)

Summary

Eight sets of monozygous twin calves were used to study the effect of aureomycin on the incidence of scours and on growth rate. From two to ten weeks of age one member of each twin set received 100 mg. per day of pure aureomycin. There was an average difference in body-weight gain over the period of 4.9 lb. in favour of the treated calves. The total incidence of scours was small. After aureomycin feeding ceased, the calves receiving it made slower weight gains than the controls. This effect persisted to 40 weeks of age.

Introduction

A great deal of work has been carried out in the United States and some in England on the value of various antibiotics for use in the rearing of pigs, poultry, lambs, and calves. Quite spectacular results have been claimed by some workers, but there are many conflicting results owing possibly to the use of proprietory preparations which makes it difficult to differentiate between the effects of the antibiotic itself and those of other accompanying factors. Other experiments are difficult to interpret because of faulty experimental designs. Confusion exists because there is no clear-cut evidence on just how the antibiotics function in increasing growth rate and improving health. The literature on the experimental work on antibiotics in relation to animal feeding has been very well reviewed by Braude *et al.* (1953). A discussion on the mode of action of antibiotics in general is presented in a review by Stokstod (1954).

The trial reported in this paper is concerned with the effect of aureomycin supplement on the growth and health of young dairy calves.

Material and Methods

Eight sets of monozygous twin calves collected from the surrounding district during the spring of 1953 were used for this trial. The calves, mainly Jerseys, were brought to the Institute farm when 3 or 4 days old.

All the calves received whole milk for the first month and were then gradually changed over to skim milk. The milk was fed at the rate of 12½% body weight. At all times the calves were rotationally grazed on pasture. The calves were weaned when they attained 200 lb. body weight, and during the summer months and early autumn when good-quality pasture was scarce because of dry weather, the calves received a supplement of meal made up of 2 parts of coconut to one part of linseed. This was fed at rates of up to 2 lb. per head per day. During the winter the calves received preferential treatment as regards the quality of pasture grazed and the hay fed.

From two to 10 weeks of age one member of each set of twins received in addition to its normal allowance of whole and/or skim milk, a supplement of aureomycin. This was fed at the rate of 100 mg.

per day in the form of a 50-mg. tablet inserted into the mouth of the treated calves at each feed. The aureomycin was in a pure crystalline form.

All calves were weighed each week on a scale accurate to 1 lb. A daily diary was kept of the health and appearance of the calves, incidence of scours, treatment for scours, and general notes on the pastures grazed.

RESULTS

The data were analysed statistically at two stages. Firstly when all the calves had reached the age of ten weeks, i.e. when the aureomycin treatment ended, and secondly, when all the calves had reached 16 weeks of age, i.e. after all the calves had been on uniform treatment for a period of 6 weeks.

For the first stage, a covariance analysis was tried using 2-weeks weight as the independent variable and 10-weeks weight as the dependent variable. However, the variance associated with the regression proved to be non significant and an ordinary analysis of variance on the growth rate of the calves from 2 to 10 weeks of age was made. This is shown in Table 1.

TABLE 1. ANALYSIS OF VARIANCE OF GROWTH RATES, 2 TO 10 WEEKS

Source	d.f.	S.S.	M.S.	F.
Total	15	2686		
B. twin sets	7	2556	365.1	73.0**
B. treatments	1	95	95.0	19.0**
Error	7	35	5.0	

** Significant at 1% level.

The control group averaged 84.1 lb. body-weight gain from 2 to 10 weeks, whilst the aureomycin-treated group averaged 89.0 lb. body weight gain for the same period. The difference in growth rate, 4.9 lb., though small was highly significant. The experiment itself at this stage was very efficient with a co-efficient of variation of 2.6% (general mean = 86.6). On calculation of the components of variance, it was found that difference between twin sets accounted for 91.7% of the total variance, while treatment differences and error variance accounted for 5.7% and 2.6% of the total variance, respectively.

TABLE 2. ANALYSIS OF VARIANCE OF GROWTH RATES, 10 TO 16 WEEKS

Source	d.f.	S.S.	M.S.	F.
Total	15	2682		
B. twin sets	7	756	108.0	3.10
B. treatments	1	1482	1482.0	42.5**
Error	7	244	34.8	

** Significant at 1% level.

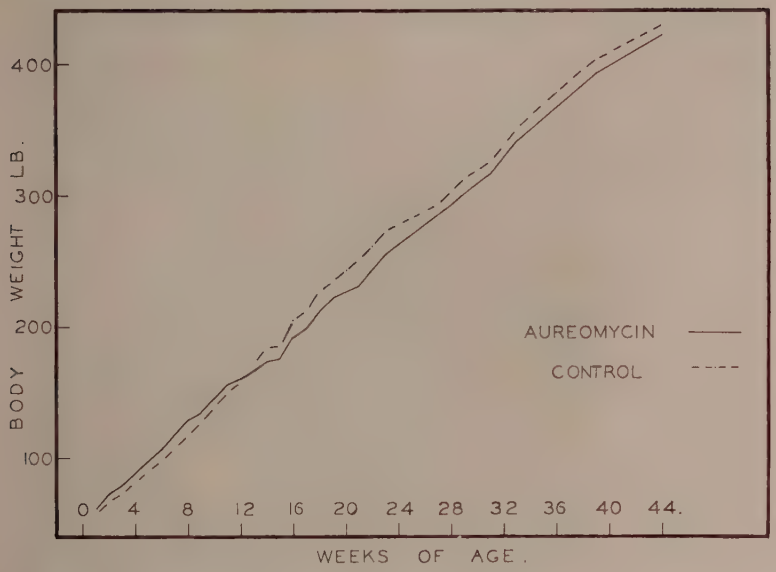


Fig. 1.—Growth curves for the control and aureomycin calves from 1 week to 44 weeks of age.

The second analysis made at 16 weeks is shown in Table 2. Control animals gained an average of 65.7 lb. over this period while aureomycin-treated animals gained 46.5 lb. The difference of 19.2 lb. was in favour of the control animals. As can be seen from Fig. 1, the aureomycin calves, after treatment had ceased, made much slower weight gains than did the control animals. The difference between the average live weights of the two groups persisted for about a year. The experiment at the 16-week stage was not as efficient as at the earlier stage, with a co-efficient of variation of 10.3 (general mean = 56.1).

There was little trouble from scouring. During the first fortnight before aureomycin feeding commenced, there were three cases of scours. Over the 2 to 10 week period there were four cases of scours, all in the control group. It was noted that treated animals had cleaner tails than control animals and were not as much affected by lush pasture. Their coats were softer and more pliable.

Discussion

This trial showed that feeding aureomycin to young calves at the rate of 100 mg. per day resulted in slightly greater weight gains during the period of treatment, but, once treatment ceased, weight gains were somewhat slower than was the case with control calves. The reason for the slower growth rate after treatment ceased is not clear. If it was because of the need for the rumen microflora to become readjusted after the treatment had ceased, then after a period for this adjustment to take place one would expect the calves to make up body weight quickly. However, the treated calves continued to be lower in average weight than the control calves at 44 weeks of age. In spite of this,

however, both groups of calves grew satisfactorily. Owing to the low incidence of scouring at any stage in the eight control calves that might be expected to scour, it is not possible to draw firmer conclusions regarding the effect of aureomycin. Management and hygiene in this trial were probably rather above average, so that aureomycin, which is most effective where management is poor and where old buildings are used (Braude *et al.* 1953), could, perhaps, scarcely be expected to show any clear-cut benefits.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the work of Mr. D. Clunie who fed and looked after the calves. Special thanks are due to W. & R. Fletcher (N.Z.) Ltd. for the gift of the aureomycin.

REFERENCES

BRAUDE, R.; KON, S. K.; PORTER, J. W. G. 1953: *Nutr. Abstr. Rev. 23:* 473.

STOKSTOD, E. L. R., 1954: *Physiol. Rev. 34:* 25.

SEED DISINFECTION

XIII. THE EFFECT OF FUNGICIDAL SEED TREATMENTS ON EMERGENCE AND COVERED-SMUT (*Ustilago kolleri* Wille) OF OATS

By H. Jacks* and I. A. M. Cruickshank†, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(Received for publication, 5 March 1956)

Summary

Nine proprietary seed dressings were tested in two field trials to determine their effect on emergence and on control of covered smut of three varieties of oats.

Granosan M. significantly reduced emergence under wet soil conditions. Other seed treatments did not significantly affect emergence.

Some organic mercury compounds were more effective than others in control of covered smut; thus Granosan M, Panogen, and Verisan gave complete control, whilst Ceresan, Agrosan GN, and Agranin, and to a lesser extent Agrimax M and Leytosan, gave significant reduction of infection. Hexachlorobenzene as Anticarie SD, although reducing the incidence of covered smut as compared with checks, was not as effective as the mercury compounds.

Under conditions favourable for smut infection, the variety Milford is more susceptible than the varieties Onward or Abundance.

Introduction

Covered smut (*Ustilago kolleri* Wille) of oats (*Avena sativa* L.) was first recorded in New Zealand by Cunningham (1927). Seed treatment of oats grown for grain with some organic mercury compounds has been standard practice for many years, and the disease is consequently of minor importance. However, smut infection is not uncommon in oat crops grown for green feed where untreated seed is sown. Tests here reported were carried out to compare the efficacy of several organic mercury compounds, and a material based on hexachlorobenzene.

Materials and Methods

Two field trials were sown at Lincoln, in April 1952 and May 1953. The oat varieties Onward, Abundance, and Milford were used.

The following seed dressings were applied: Agranin (2.2% alcoxy alkyl mercury) dust; Agrimax M (4% phenyl mercuric dinaphthyl methane disulphonate) dust; Agrosan GN (1% tolyl mercury acetate) dust; Ceresan (1.5% phenyl mercury acetate + ethoxy alkyl mercury chloride) dust; Granosan M (7.7% ethyl mercury p-toluene sulphonamide) dust; Leytosan (1.6% phenyl mercury chloride) dust; Panogen (1.2% methyl mercury dicyan diamide) liquid; Verisan (3.5% methoxy ethyl mercury) dust; Anticarie SD (11.2% chlorine in combination with polychlorobenzene) dust.

Seed was inoculated in 1952 by mixing 0.5 g. of smut spores and 500 g. of seed in a sealed flask. A spore suspension technique (Popp

*Now at Massey Agricultural College, Palmerston North.

†Stationed at Crop Research Division, D.S.I.R., Christchurch.

and Cherewick, 1952) was used in 1953 viz. 2 g. of spores in 1 litre of water to 500 g. of seed agitated in a Waring Blendor for 25 seconds followed by slow drying at room temperature.

Seed dressings were applied after inoculation at the rate of 2 oz. per bushel.

Six replications, each consisting of an 8-ft. row per treatment and variety, were sown with 100 seeds at a depth of approximately 2 in. Emergence counts were made 4 weeks after sowing and smut infection was recorded when the plants were in ear.

Records* for rainfall and soil temperatures were as follows:

Rainfall: April 1952, 0.83 in.; May 1953, 2.38 in. Total rainfall recorded January to April 1952, 4.48 in., January to May 1953, 16.6 in.
Means soil temperature: April 1952, 54.3°F. May 1953, 47.2°F.

RESULTS

Results of field trials presented in Table 1 were calculated over all varieties.

TABLE 1. RESULTS OF SEED TREATMENT IN 1952/53 AND 1953/54 CALCULATED OVER ALL VARIETIES

	Mean Percentage Emergence		Mean Percentage Smut-infected Plants		
			1952–53		1953–54
	1952–53	1953–54	%	Equiv. angle	%
Check (no treatment)	72.2	78.8	37.6	37.8	5.3
Agranin	76.1	—	1.4	6.6	—
Agrimax M	76.1	—	4.6	12.4	—
Agrosan GN	71.5	80.1	1.3	6.7	0.4
Anticarie SD	70.2	—	22.8	28.5	—
Ceresan	78.9	80.1	0.2	2.5	0.3
Granosan M	68.4	56.2	0.0	0.0	0.0
Leytosan	71.7	—	3.9	11.4	—
Panogen	67.4	77.8	0.0	0.0	0.0
Verisan	76.4	76.0	0.0	0.0	0.0
Sig. diff: at 1%	7.3	4.7	—	5.5	—

Analysis of emergence counts showed that the interaction of variety and treatment and of treatments irrespective of variety was not significant, with the exception of Granosan M which under cool wet soil conditions prevailing at time of sowing in 1953 significantly reduced establishment in all varieties, especially that of the variety Abundance.

* Supplied by Canterbury Agricultural College, Lincoln.

Three materials, viz. Granosan M, Panogen, and Verisan, gave complete control of covered smut and were not included in the analysis. All other treatments gave significant reduction of infection over checks in 1952–53, with Ceresan, Agranin, and Agrosan GN significantly better than Agrimax M and Anticarie SD. In 1953–54, materials giving complete smut control in 1952–53 were used in addition to the two mercury compounds (Agrosan GN and Ceresan) used commercially in New Zealand. No analysis of smut control was attempted since the level of infection in the checks was too low. The three materials, however, that had given complete control in the first trial were again more effective than Agrosan GN and Ceresan.

A comparison of the percentage smut infection in the checks of the three varieties showed that in 1952–53 Onward had significantly less infection than Abundance or Milford (15.8%, 36.5%, 65.9% respectively). A similar result was obtained when smut infection in the three varieties was compared irrespective of treatment. (2.4%, 7.9%, 11.9% respectively).

DISCUSSION AND CONCLUSIONS

The action of mercury as a soil fungicide has been discussed by Booer (1951). It is shown that mercury compounds retard growth of both plants and fungi and that if applied in excess of optimal dosage phytocidal effects may result. It is suggested that the reduction of stand brought about by Granosan M in 1953–54 under cool and wet soil conditions (see meteorological records) can be explained on this basis.

Cereal smuts as a group are favoured by low soil moisture content (Garrett, 1944). This is clearly confirmed by the difference in level of smut infection between the two field trials.

From the results of these tests it appears that the application of materials based on methyl mercury dicyan diamide and methoxy ethyl mercury at the rate of 2 oz. per bushel of seed gives complete control of covered smut.

The varieties under test showed in 1952–53 a variable level of susceptibility to infection. The variety Milford showed significantly higher incidence of covered smut than the varieties Onward or Abundance.

ACKNOWLEDGEMENT

Thanks are expressed to Mr. G. M. Wright of the Crop Research Division, Department of Scientific and Industrial Research, for statistical analysis of data presented in this paper.

REFERENCES

BOOER, J. R. 1951: *Ann. appl. Biol. 38:* 334-47.

CUNNINGHAM, G. H. 1927: *Trans. N.Z. Inst. 58:* 47.

GARRETT, S. D. 1944: "Root Disease Fungi", p.42. Chronica Botanica, Waltham, Mass.

POPP, W.; CHEREWICK. W. J. 1952: *Phytopathology 42:* 472.

RESISTANCE OF SWEDES TO APHIDS

II. DISTRIBUTION OF APHIDS ON SWEDES

By T. P. Palmer, Crop Research Division, Department of Scientific and Industrial Research, Christchurch.

(Received for publication, 30 December 1955)

Summary

Aphids were counted on the varieties Calder and Grandmaster in 1951, and on Calder, Wilhelmsburger, and Superlative in 1953.

Calder and Wilhelmsburger supported fewer *Brevicoryne brassicae* than Superlative or Grandmaster.

Calder carried as many *Myzus persicae* as Superlative but Wilhelmsburger supported lower populations of this aphid.

B. brassicae were more numerous, and also more crowded on young leaves than on old leaves of all varieties, but leaves of resistant varieties appeared to become resistant at an earlier stage than leaves of susceptible varieties.

M. persicae, however, were more numerous on old leaves than on young leaves, but they, also, were less dense on the older leaves. However, the reduction in density between old and young leaves was much less than with *B. brassicae*.

These findings are consistent with the known difference in host range of the two species of aphid.

Introduction

Aphids, principally *Brevicoryne brassicae*, are a serious pest on cruciferous crops in some parts of New Zealand, and in the Canterbury province they not infrequently destroy whole crops of rape (*B. napus* L.), swedes (*B. napus* L. var. *napo-brassica*), and turnips (*B. rapa*). In some years, *Myzus persicae* also occurs in large numbers on these crops, but the heaviest infestations of this species do not reach the epidemic proportions attained by *B. brassicae*.

Some varieties of swedes are known to be resistant to *B. brassicae* (Palmer 1953). On these resistant varieties aphids are not as numerous as on susceptible varieties (Lamb 1953, Palmer unpubl.), and the resistant swedes appear to recover from aphid attack more rapidly and completely than susceptible varieties.

Aphids have been counted on susceptible and resistant varieties during the past few years. Results from these counts in the main showed merely that the resistant varieties carried fewer aphids than susceptible varieties, a fact which was already known (Lamb 1953).

Additional information on the distribution of *B. brassicae* and *M. persicae* on susceptible and resistant varieties has been obtained, and is presented in this paper.

Experimental Methods

In 1951, the aphids on each leaf of 40 Grandmaster and 40 Calder swede plants were counted. In 1953, aphids were counted on each leaf of 16 Calder, Wilhelmsburger Otofte, and Superlative plants. Grand-

master and Superlative are susceptible varieties, Wilhelmsburger Otofte and Calder are resistant.

In 1951, the plants on which aphids were counted were from a randomized block trial containing two other varieties. Plots consisted of 4 rows 25 ft. long and 2 ft. 3 in. apart. Samples were taken from four replications of this trial. The trial in 1953 was similar to that conducted in 1951, plots consisting of five rows each 30 ft. long. In 1951, only *B. brassicae* occurred on the swedes, but in 1953 considerable numbers of *M. persicae* were present as well.

RESULTS AND DISCUSSION

The 1951 results are presented in Tables 1 and 2.

B. brassicae were most numerous on the young leaves of all varieties, while the oldest leaves were almost free from aphids. Aphids often concentrate on leaves of certain ages, and are absent or rare on others (Kennedy *et al.* 1950). The distribution of *B. brassicae* on swedes could have resulted from winged immigrants founding colonies on young rather than on old leaves (see Table 2, also Ibbotson 1953), or by the movement of wingless females from older to younger leaves, or perhaps by a greater fecundity or lower death rate of aphids living on younger leaves. Whatever the cause, the younger leaves may be called susceptible,

TABLE 1. DISTRIBUTION OF WINGLESS FEMALES ON CALDER AND GRANDMASTER SWEDES

	Numbers		Percentage of Total on Each Leaf				Density[3]	
	Calder	Grand-master	Calder	Grand-master	Calder[1]	Grand-master[2]	Calder	Grand-master
Leaf 1	188	327	44.4	26.9	42.2	32.7	261	511
2	116	311	27.4	25.5	33.8	25.3	68	116
3	34	225	8.0	18.5	5.4	14.3	5.6	46
4	19	190	4.5	15.6	4.1	13.8	2.5	37
5	23	101	5.4	8.3	6.1	9.2	3.5	43
6	27	55	6.4	4.5	4.7	3.2	5.3	20
7	10	8	2.4	0.7	1.0	1.4	3.8	8.2
8	6	0	1.4	0	2.0		8.1	
Total	423	1217						
No. of plants	40	40	40	40	15	20		
Mean no. per plant	10.6	30.4			19.8	10.9		

1. Heavily infested Calder plants.
2. Lightly infested Grandmaster plants.
3. Number of aphids per gm. oven dry weight of leaf.

TABLE 2. DISTRIBUTION OF WINGED FEMALES ON CALDER AND GRANDMASTER SWEDES

	Number		%	
	Calder	Grandmaster	Calder	Grandmaster
Leaf 1	13	8	57	12
2	6	18	26	27
3	2	13	8	19
4	1	17	4	25
5	1	9	4	13
6	0	1	0	2
7	0	1	0	2
8	0	0	0	0
Total	23	67		
Mean per plant	0.58	1.68		

and the older leaves resistant. In fact, a much greater difference was found between leaves of any one variety than between varieties.

However, the youngest leaf of Calder carried fewer aphids than the youngest leaf of Grandmaster. And whereas most of the aphids on Calder occurred on the first two leaves, and particularly the first, the aphids on Grandmaster were abundant on the first four or five leaves. Thus, the wingless females were more evenly spread over the leaves of the susceptible plants.

This difference was not merely a reflection of the more crowded condition on the susceptible plants, for the distribution on the less densely populated Grandmaster plants, with a mean population about the same as that of Calder, was similar to that for Grandmaster as a whole. On the more crowded Calder plants, the distribution was similar to that on the rest, even though the more heavily infested Calder plants carried more aphids than the lightly infested Grandmaster plants.

It seems reasonable to conclude that leaves of swedes become resistant to *B. brassicae* as they age, but that leaves of resistant varieties develop this resistant quality sooner than leaves of susceptible varieties.

The plants on which aphids were counted in 1953 were older, and the number of leaves more variable. Leaves were divided arbitrarily into two age groups, young leaves being the first four leaves, and old leaves being the last four.

Again in 1953, *B. brassicae* were fewer on old than on young leaves, and on resistant than on susceptible varieties. The figures for aphid density accentuate these differences.

M. persicae, however, were not distributed in this way. Both Calder and Superlative carried about the same numbers of this aphid, while Wilhelmsburger carried substantially fewer. The old leaves of all varieties

TABLE 3. NUMBERS OF WINGLESS FEMALES PER LEAF ON YOUNG AND OLD LEAVES

	M. persicae			*B. brassicae*		
	Calder	Will.	Super.	Calder	Will.	Super.
Young leaves	50.11	18.94	46.51	2.11	2.81	19.19
Old leaves	92.13	46.21	98.28	1.35	0.77	8.38

TABLE 4. DENSITY* OF WINGLESS FEMALES ON YOUNG AND OLD LEAVES

	M. persicae			*B. brassicae*		
	Calder	Will.	Super	Calder	Will.	Super.
Young leaves	22.41	4.97	27.91	.94	.88	11.52
Old leaves	2.47	1.36	3.74	.036	.023	.32

*Density = number of aphids per gm. green leaf.

carried about twice as many *M. persicae* as the young leaves, though, as with *B. brassicae*, the aphids were less dense on the older leaves. But whereas the *B. brassicae* were 30–40 times as dense on the young leaves, *M. persicae* were only about 5–10 times as dense on the young leaves.

M. persicae has a wide host range while *B. brassicae* is confined to one family of plants. It is not, then, surprising to find that numbers of *M. persicae* on some swedes resistant to *B. brassicae* are as high as on varieties susceptible to *B. brassicae*, or that *M. persicae* are less affected by leaf age than *B. brassicae*.

ACKNOWLEDGEMENT

Thanks are due to K. Doull and B. Watts of Canterbury Agricultural College for help in identifying aphid species.

REFERENCES

IBBOTSON, A. 1953: Studies of Cabbage-aphis Infestation on Brussels Sprouts, 1951. *Plant Path. 2:* 25-30.

KENNEDY, J. A.; IBBOTSON, A.; BOOTH, C. O. 1950: The Distribution of Aphis Infestation in Relation to Leaf Age. *Ann. appl. Biol. 37:* 651-79.

LAMB, K. P. 1953: Field Trials of Five Swede Varieties with Special Reference to Aphis Resistance. *N.Z. J. Sci. Tech. A. 35:* 135-45.

PALMER, T. P. 1953: Resistance of Swedes to Aphids. I. Resistant Varieties. *N.Z. J. Sci. Tech. A. 34:* 553-5.

THE USE OF CHEMICAL THINNING SPRAYS ON APPLE TREES IN NEW ZEALAND

III. EFFECT ON FRUIT STORAGE LIFE

By R. M. DAVISON, Fruit Research Station, Department of Scientific and Industrial Research, Auckland

(Received for publication, 1 December 1955)

Summary

Cool-storage tests were carried out with fruit samples from chemically thinned trees of five apple varieties, Sturmer, Jonathan, Dougherty, Statesman, and Dunn's Favourite. Two chemical thinning treatments, a full-bloom spray of sodium dinitro-ortho-cresylate (DNOC) or a post-blossom spray of alphanaphthaleneacetic acid (ANA) were used.

Fruit from Sturmer trees thinned with ANA at 100% petal fall showed, in some experiments, a greater incidence of internal breakdown than fruit from unsprayed hand-thinned trees or from DNOC-sprayed trees. Reductions of up to 30% of commercially sound fruit resulted. Fruit from Sturmer trees thinned with DNOC, although considerably larger, in general stored as well as fruit from unsprayed hand-thinned trees.

With other varieties, storage life was not as markedly affected by treatments, although in some experiments more internal breakdown and coreflush occurred, with a consequent reduction in commercially sound fruit.

Losses caused by internal breakdown in fruit from Sturmer trees thinned with ANA were reduced by early picking.

INTRODUCTION

Field results obtained with chemical thinning sprays in New Zealand districts have been reported previously (Davison, 1955a, b). Fruit samples from trees used in these and similar trials were placed in cool-store to assess the effects of alphanaphthaleneacetic acid (ANA) and sodium dinitro-ortho-cresylate (DNOC) on storage life.

A preliminary note of results has been published (Davison, 1954). A more detailed account of these experiments is given below.

METHODS

Storage samples consisted of a half-bushel or bushel case of fruit from each tree. Average fruit size varied considerably between treatments and samples were selected from fruit representing the average size of the tree. An indication of size is given by the mean number of fruit per case.

In all experiments storage samples were taken at the usual harvesting time for the variety. In the 1952–53 Hawke's Bay experiment on Sturmer, additional samples, picked 23 days earlier, were stored. In addition to the sample cases from each tree, small composite samples representing each treatment were stored in inspection cases for periodical observation of the general condition of the stored line.

Samples were placed in cool store within ten days of harvest. In most experiments samples remained in store for the usual commercial

period for each variety unless a 10% loss of fruit from any one disorder occurred in the inspection samples. If such loss was noted, the line was immediately removed from store. Jonathans in 1952–53 were stored beyond the usual commercial period.

After cool storage, all lines, except Jonathan in 1952–53, were held for fourteen days at air temperature before examination. Jonathans in 1952–53 were held for only five days.

All fruits were examined externally and in section. Disorders were recorded only when commercially significant. Fruits with a disorder of this severity in most instances would have been unmarketable or of low commercial value.

General descriptions of the disorders recorded have been given by Padfield (1954). Details of treatments, and dates of harvest, storage, and examination, are given in the Tables.

RESULTS

Results are recorded in Tables 1, 2 and 3. Only figures for the most prevalent disorders are given. A small percentage of fruits in most experiments was effected by other disorders, the incidence of which was not correlated with treatment.

Sturmer (Table 1)

Internal breakdown was the main cause of loss of fruit in all experiments. Treatment with ANA thinning sprays led to a marked increase in incidence of this disorder in fruit of the main pickings in Hawke's Bay in both 1951–52 and 1952–53 seasons. As a result, the number of commercially sound fruit was reduced by up to 30%. Fruit from trees thinned with DNOC, although of a much larger size, stored as well as fruit from hand-thinned trees.

Losses from internal breakdown were reduced by early picking. Although differences between treatments are not significant at the 5% level with the early pick, fruit from ANA-thinned trees still showed almost three times more internal breakdown than fruit from hand-thinned checks.

Thinning sprays of DNOC and ANA in Nelson affected storage of samples only slightly and differences in commercially sound fruit were not significant at the 5% level.

Jonathan (Table 2)

In the 1952–53 Nelson experiment, in which samples were held in cool store for a period of five months, fruit from trees thinned with ANA developed more internal breakdown and coreflush than that from hand-thinned check trees, and the percentage of commercially sound fruit was reduced considerably. Differences, however, were not significant at the 5% level.

In later experiments in Hawke's Bay and Nelson, fruit from chemically thinned trees kept as well as fruit from unsprayed trees when samples were stored for approximately two months, the usual storage period for this variety.

TABLE 1. STORAGE DISORDERS IN STURMER APPLES

Treatment	No. Days Cool Storage	Av. No. Fruit per Case	Wilt		Internal Breakdown		Commercially Sound	
			%	Angle	%	Angle	%	Angle
Hawke's Bay 1951–52								
Picked 8/4/52. Stored 9/4/52								
Examined 22–23/8/52	130	123			8.9	14.0	90.4	74.2
Unsprayed, hand thinned								
DNOC 1¼ pt./100 gall. Full bloom		98			10.7	16.5	89.1	72.3
ANA 20 p.p.m. 100% petal fall		113			35.1	35.1	64.6	54.6
Diff. for sig. 5%						9.3		9.9
1%						13.2		14.0
Hawke's Bay 1952–53								
Early Picking								
Picked 17/3/53. Stored 18/3/53								
Examined 31/8/53–2/9/53	152							
Unsprayed, hand thinned		150	5.9	12.5	5.8	10.3	87.9	70.3
DNOC 1¼ pt./100 gal. Full bloom		99	1.1	12.8	6.2	10.7	87.4	70.8
ANA 15 p.p.m. 100% petal fall		125	10.9	19.0	17.1	20.8	72.9	59.7
Diff. for sig 5%				8.8		19.3		14.3
1%				12.9		28.6		21.1
Main Picking								
Picked 9/4/53. Stored 14/4/53								
Examined 28/9/53	152							
Unsprayed, hand thinned		148	13.6	21.3	26.0	28.5	61.0	51.7
DNOC 1¼pt./100 gal. Full bloom		74	5.4	13.1	27.7	18.8	63.3	62.2
ANA 15 p.p.m. 100% petal fall		128	15.6	23.2	60.1	50.9	30.3	32.9
Diff. for sig. 5%				8.3		14.1		12.4
1%				12.3		20.8		18.3
*Nelson 1952-53**								
Picked 22/4/53. Stored 23/4/53								
Examined 2/10/53	147							
Unsprayed, hand thinned		45			10.8	18.8	85.8	68.0
DNOC 1½ pt./100 gal. Full bloom		42			18.4	24.0	77.3	62.8
Diff. for sig. 5%						18.2		15.9
1%						30.1		26.3
Nelson 1953–54								
Picked 23/4/54. Stored 3/5/54								
Examined 3/11/54	169							
Unsprayed, hand thinned		151					92.9	75.7
ANA 10 p.p.m. 100% petal fall		133					90.9	73.4
Diff. for sig. 5%								22.1
1%								36.7

* Denotes experiments in which half-bushel samples were stored. Otherwise bushel samples were stored.

TABLE 2. STORAGE DISORDERS IN JONATHAN APPLES

Treatment	No. Days Cool Storage	Av. No. Fruit per Case	Jonathan Spot		Coreflush		Internal Breakdown		Commercially Sound	
			%	Angle	%	Angle	%	Angle	%	Angle
Nelson 1952–53 †*										
Picked 17/3/52. Stored 18/3/52										
Examined 1/9/53	151									
Unsprayed, hand thinned		54			2.4	5.3	19.2	24.3	80.4	64.9
ANA 10 p.p.m. 1 week after petal fall		51			7.8	14.2	40.4	39.1	56.4	48.9
Diff for sig. 5%						15.1		21.1		20.8
1%						25.0		34.9		34.4
*Nelson 1953–54**										
Picked 29/3/54. Stored 5/4/54										
Examined 18/6/54	60									
Unsprayed		50							98.4	85.1
DNOC 1½ pt./100 gal. Full bloom		46							96.8	81.8
ANA 10 p.p.m. 100% petal fall		45							96.3	80.2
Diff for sig. 5%										6.5
1%										9.3
Hawke's Bay 1953–54										
Picked 5/3/54. Stored 12/3/54										
Examined 31/5/54	66									
Unsprayed, hand thinned		148	22.1	27.4					67.4	56.6
ANA 15 p.p.m. 100% petal fall		148	24.9	29.4					72.5	58.9
Diff for sig. 5%				19.8						17.6
1%				31.1						27.6

* Denotes experiments in which half bushel samples were stored. Otherwise bushel samples were stored.

† Held for only five days after removal from cool store.

Dougherty (*Table 3*)

Coreflush was the main disorder recorded on this variety. In 1952–53 both ANA and DNOC samples showed less of this disorder than checks. However, there was little difference between treatments in the percentage of commercially sound fruit.

In 1953–54 chemical treatments, particularly DNOC, caused appreciable storage losses. Samples from trees receiving the double spray of DNOC showed increased internal breakdown and a greater incidence of fungous infection. Fruit from ANA-sprayed trees developed significantly more coreflush and internal breakdown than fruit from unsprayed trees.

Most of the fungus recorded in this season was ripe rot.

Dunn's Favourite (*Table 3*)

Fruit from trees thinned with ANA stored slightly better than fruit from unsprayed trees, but the difference in percentage of commercially sound fruit was not significant at the 5% level. Spraying

TABLE 3. STORAGE DISORDERS IN DOUGHERTY, DUNN'S FAVOURITE, AND STATESMAN APPLES

Treatment	No. Days Cool Storage	Av. No. Fruit per Case	Superficial		Fungus		Coreflush		Internal Breakdown		Commercially Sound	
			%	Angle	%	Angle	%	Angle	%	Angle	%	Angle
Dougherty. Hawke's Bay 1952–53												
Picked 23/4/53. Stored 23/4/53												
Examined 14–15/10/53	159											
Unsprayed, hand thinned		145					22.7	27.6			75.6	61.0
DNOC 1¼ pt./100 gal. Full bloom		113					11.0	18.7			80.8	64.6
ANA 20 p.p.m. 50% petal fall.		136					12.0	20.3			82.2	65.2
Diff. for sig. 5%								7.3				7.5
1%								10.6				10.6
Dougherty. Hawke's Bay 1953–54												
Picked 3-8/5/54. Stored 12/5/54												
Examined 7–8/9/54	103											
Unsprayed, hand thinned		131			1.0	2.6	5.9	12.1	0	0	92.9	76.1
DNOC 1½ pt./100 gal. Double spray		125			12.4	20.4	5.3	11.4	7.6	12.5	76.0	61.5
ANA 20 p.p.m. 50% petal fall		123			4.3	10.3	11.6	19.2	1.0	2.4	83.8	67.1
Diff. for sig. 5%						5.8		4.9		7.0		6.0
1%						8.3		7.0		11.6		8.6
*Dunn's. Nelson 1952–53**												
Picked 4-5/3/53. Stored 5/3/53												
Examined 15/9/53	179											
Unsprayed, hand thinned		45	24.0	28.5			13.4	21.1	3.0	7.5	66.7	55.1
DNOC 1½pt./100 gal. Full bloom		42	24.4	27.8			30.4	32.9	10.0	17.4	55.1	48.1
ANA 20 p.p.m. 1 week after petal fall		44	7.8	13.9			12.6	19.9	4.8	10.7	72.7	58.7
Diff. for sig. 5%				12.6				5.6		6.5		11.2
1%				18.3				8.1		9.4		16.2
Statesman. Nelson 1953–54												
Picked 23/4/54. Stored 3/5/54												
Examined 13/10/54	152											
Unsprayed, hand thinned		138					37.2	37.5	5.2	12.9	51.2	45.7
DNOC 1½ pt./100 gal. Full bloom		132					46.9	43.1	16.2	23.3	45.3	42.2
ANA 20 p.p.m. 100% petal fall		132					33.0	35.0	11.5	19.7	52.9	46.7
Diff. for sig. 5%								6.1		4.1		7.3
1%								8.7		5.8		10.3

* Denotes experiments in which half-bushel samples were stored. Otherwise bushel samples were stored.

with DNOC produced an increase in both internal breakdown and coreflush, but again the difference in percentage of commercially sound fruit was not significant.

Statesman (Table 3)

Storage losses were caused mainly by coreflush, internal breakdown, and fungous infection. Compared with hand thinning, DNOC slightly increased and ANA slightly decreased coreflush, but differences were not significant at the 5% level. Both ANA and DNOC increased internal breakdown but no significant differences in percentage of commercially sound fruit were demonstrated. These latter figures however include unexplained high losses in certain samples caused by soft-rotting fungi.

DISCUSSION

The demonstration that chemical thinning sprays will reduce storage life of certain apple varieties is important because of the likely widespread adoption of such methods. The pronounced effect of ANA petal-fall sprays on storage life of Sturmers is of considerable consequence, since this variety is the main long-storage apple grown in New Zealand. On other varieties tested, chemical thinning sprays of DNOC at full bloom and ANA at petal fall have also shown a slight tendency in some seasons to reduce storage life, mainly through increased losses caused by internal breakdown or coreflush.

When fruit from chemically thinned trees is compared in store with fruit from hand-thinned trees, some additional loss from internal breakdown can be attributed to larger size. This may explain slight variations in storage performance evident in certain of the experiments. Because an increase in fruit size is usual, following use of chemical thinning sprays, it is probable that a slight reduction in storage life will always occur with the method. However, size differences alone cannot explain the marked differences in incidence of internal breakdown between fruit from ANA-thinned trees and hand-thinned trees recorded in the Sturmer experiments. Some additional effect of the spray seems to be responsible for these losses. It is of interest to note that in the Hawke's Bay Sturmer experiments, large fruit from DNOC-thinned trees kept as well as much smaller fruit from hand-thinned trees. No explanation for this result can be advanced.

The absence of a marked effect of ANA on storage life of Sturmer in Nelson in 1953–54 is notable. This line stored particularly well and only a small percentage of internal breakdown was recorded. Use of a concentration of ANA in Nelson (10 p.p.m.) lower than that needed in Hawke's Bay (15 to 20 p.p.m.) may account for this lack of effect.

Experience in U.S.A. (Hoffman; Murneek, pers. comm., 1954) suggests that a growth-inhibiting and pre-ripening effect on apple fruits may occur if ANA thinning sprays are used some weeks after full bloom. It is mainly early varieties that have been reported to be affected. It is apparent that ANA applied even 10 days after full bloom may cause on the late variety Sturmer a similar pre-ripening effect, which leads to an increase in maturity breakdown in store. A possible way of avoiding such losses in storage while still using ANA for thinning Sturmers is to make applications at an earlier stage of development, for example at

full bloom or early petal fall. Experiments to test the effect of such applications on storage life are being undertaken.

Results obtained in the present experiments suggest that it might be possible to reduce this adverse effect of ANA on storage life of Sturmer by picking a considerable time ahead of the usual date. Such an advance in picking time in most instances would be impracticable.

ACKNOWLEDGEMENT

Thanks are due to Dr. H. R. Thompson, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, Wellington, for analysis of data.

REFERENCES

DAVISON, R. M. 1954: *Orchard. N.Z. 27(8):* 5.

———— 1955a: *N.Z. J. Sci. Tech. A36:* 505-15.

———— 1955b: *Ibid. 37:* 1-7.

PADFIELD, C. A. S. 1954: *N.Z. Dep. sci. industr. Res. Bull. 111:* 96 pp.

THE USE OF CHEMICAL THINNING SPRAYS ON APPLE TREES IN NEW ZEALAND

IV. COMPATIBILITY OF GROWTH SUBSTANCES WITH THERAPEUTANT SPRAYS

By R. M. Davison, Fruit Research Station, Department of Scientific and Industrial Research, Auckland

(Received for publication, 1 December 1955)

Summary

Alphanaphthaleneacetic acid (ANA) and alphanaphthaleneacetamide, applied alone or mixed with therapeutant sprays, were tested as thinning agents on Jonathan apples in Nelson.

ANA was effective and caused no additional foliage injury when combined with one or several of the following: Lime sulphur, colloidal sulphur, phenyl mercury chloride, thiram, ferbam, captan, lead arsenate, summer oil, DDT, DDD, hydrated lime.

ANA tended to be more effective when applied with therapeutants than when applied alone.

The acetamide achieved more thinning mixed with summer oil than applied alone although the increase in effectiveness was not significant.

Introduction

The use of plant-growth-substance sprays as chemical fruit-thinning agents on apples in New Zealand fruit-growing districts has been reported previously (Davison, 1955a, b). As applications coincide approximately with early-post-blossom therapeutant sprays, inclusion of thinning chemicals in such routine sprays is a possibility.

Combinations of ANA (alphanaphthaleneacetic acid) with other spray chemicals have been tested by many workers on pre-harvest drop of apples. ANA was found compatible with most sprays, although some reports suggested that lime caused a loss of effectiveness, e.g. Khadow and Hopperstead (1942). Addition of summer oil to ANA and the acetamide (alphanaphthaleneacetamide) was reported by Gardner *et al.* (1940) to increase effectiveness of the growth-substance sprays. Other workers have not always supported this conclusion (Hoffman, 1941).

Davidson *et al.* (1945) reported that the sodium salt of ANA was effective as a thinning chemical when applied with wettable sulphur, and with wettable sulphur plus hydrated lime. Brough (pers. comm.) in Australia found ANA effective when mixed with petal-fall sprays of lime sulphur and summer oil. He also reported that addition of summer oil to ANA sprays increased the thinning effect of the growth substance.

Experiments to test the compatibility of growth substances (as thinning agents) with therapeutant sprays commonly used on apples in New Zealand orchards were carried out in Nelson in the following seasons 1951-52, 1952-53, 1953-54, 1954-55. An account of these trials is given below.

Methods

In all experiments, mature Jonathans were used, each treatment being applied to 5 or 6 trees randomized within blocks as single-tree plots,

The method of recording effectiveness of treatments was by limb counts as described by Davison (1955a). Observations for foliage effects were also made. Sprays were applied by portable orchard unit using a double-nozzle lance.

Two growth substances were used:

Alphanaphthaleneacetic acid (ANA), either as the pure chemical (1951-52) or as the pre-harvest-drop formulation, Planofix.

Alphanaphthaleneacetamide, as Amid-Thin, formulated specifically for thinning purposes.

Therapeutant chemicals used were:

Phenyl mercury chloride as Venturicide—a wettable powder containing 2.5% active chemical.

Thiram as Thirospray—a wettable powder containing 50% technical tetramethyl thiuram disulphide.

Ferbam as Fermspray—a wettable powder containing 70% technical ferric dimethyl dithio-carbamate.

Captan as Flit-406—a wettable powder containing 50%

N-trichloromethyl thio tetrahydrodropthalimide.

Colloidal sulphur—25% colloidal sulphur

Lime sulphur—15% polysulphides

DDD.

DDT.

Lead arsenate

Hydrated lime

Summer oil.

Quantities of therapeutant chemicals given in the table represent the amount added to 100 gallons of water.

Results

Details of treatments and results are given in Table 1.

The application of ANA with various therapeutant mixtures caused no loss of effectiveness of the growth substance as a thinning agent. When combined with therapeutants, ANA tended to thin more than when applied alone, although in no instance was the difference significant. Addition of summer oil also tended to increase effectiveness of the acetamide although the increase was not significant.

In 1952–53, slight foliage wilting, which disappeared within two weeks, occurred on all sprayed trees. No injury was observed in other seasons.

TABLE 1. EFFECTIVENESS OF ALPHANAPHTHALENEACETIC ACID (ANA) AND ALPHANAPHTHALENEACETAMIDE AS THINNING AGENTS ALONE AND COMBINED WITH THERAPEUTANT SPRAYS

Treatment	Time of application	No. fruits /100 clusters
*1951–52**		
Unsprayed		71.8
ANA 10 p.p.m.	10 days after 100% petal fall	50.9
ANA 10 p.p.m. + lime sulphur ½ gal., colloidal sulphur 2 lb., DDT. ¼ lb. p.p.i., DDD. ½ lb. p.p.i.	,,	54.3
Sig. diff. 5%		*14.1*
1%		*20.3*
1952–53		
Unsprayed		64.4
ANA 10 p.p.m.†	100% petal fall	46.2
ANA 10 p.p.m. + lime sulphur ½ gal., colloidal sulphur 2lb., lead arsenate 1½ lb., hydrated lime 3 lb.	,,	40.1
ANA 10 p.p.m. + lime sulphur ½ gal., colloidal sulphur 2 lb., DDT. ½ lb. p.p.i.	,,	39.4
ANA 10 p.p.m. + phenyl mercury chloride (Venturicide 2 lb.), lead arsenate 1½ lb.	,,	33.5
Sig. diff. 5%		*16.1*
1%		*21.9*
1953–54		
Unsprayed		40.5
ANA 10 p.p.m.	100% petal fall	24.8
ANA 10 p.p.m. + summer oil 1 pint	,,	19.7
ANA 10 p.p.m. + colloidal sulphur 4 lb., lead arsenate 1½ lb., hydrated lime 3 lb.	,,	23.3
ANA 10 p.p.m. + thiram (Thirospray 2 lb.)	,,	19.7
ANA 10 p.p.m. + ferbam (Fermspray 2 lb.)	,,	11.8
Sig. diff. 5%		*17.6*
1%		*23.9*
1954–55		
Unsprayed		74.7
ANAcetamide 25 p.p.m.	95% petal fall	48.7
ANAcetamide 25 p.p.m. + summer oil 1 pint	,,	38.5
ANA 10 p.p.m.	,,	54.3
ANA 10 p.p.m. + summer oil 1 pint	,,	44.5
ANA 10 p.p.m. + ferbam (Fermspray 2 lb.)	,,	49.7
ANA 10 p.p.m. + captan (Flit 406 2 lb.)	,,	48.8
Sig. diff. 5%		*12.6*
1%		*17.0*

* ANA sprays were prepared by dissolving the chemical in alcohol before adding to the tank. A spreader, Agral LN, was added to ANA 10 p.p.m. alone but not to the combination.

† The application of ANA 10 p.p.m. alone was made the day before other sprays.

Discussion

ANA as a thinning agent was effective when added to a range of therapeutant chemicals, and no additional foliage injury occurred. Results suggest that, in practice, thinning can be carried out by addition of ANA to early-post-blossom therapeutant sprays.

The tendency for summer oil to increase effectiveness of ANA and the acetamide supports the results of Brough (pers. comm.) who also stated that addition of the oil to ANA sprays reduced wilting of foliage. As foliage was not markedly affected by sprays in the Nelson experiments, this latter result was not confirmed. If summer oil as an additive does in fact increase effectiveness of growth substances as thinning chemicals, and at the same time reduces foliage wilt, its inclusion would be of particular value on those varieties with foliage susceptible to damage from growth substances.

The evidence for a slight increase in effectiveness of ANA when applied with most therapeutant mixtures is perhaps indicative of more efficient spreading or sticking with the mixtures than with ANA alone.

Acknowledgements

Thanks are due to Dr. H. R. Thompson, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, for statistical analysis of data. Samples of Amid-Thin were kindly supplied by Ivon Watkins Ltd., New Plymouth.

References

Davidson, J. H.; Hammer, O. H.; Reimer, C. A.; Dutton, W. C. 1945: *Quart. Bull. Mich. agric. Exp. Sta. 27:* 352-6.

Davison, R. M. 1955a: *N.Z. J. Sci. Tech. 36:* 506-15.

————1955b: *Ibid. 37:* 1-7.

Gardner, F. E.; Marth, P. C.; Batjer, L. P. 1940: *Proc. Amer. Soc. hort Sci. 37:* 415-28.

Hoffman, M. B. 1941: *Bull. Cornell. agric. Exp. Stat. 766:* 18.

Khadow, K. J.; Hopperstead, S. L. 1942: *55th Trans. Peninsula hort. Soc. 31:* 32-4.

EFFECT OF VARIOUS GROWTH-REGULATING SUBSTANCES ON FRUIT DROP AND STORAGE LIFE OF APPLES

By R. M. Davison, Fruit Research Station, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 1 December 1955*)

Summary

In experiments carried out to test the effectiveness of several growth substances in reducing pre-harvest drop of apples, both alphanaphthaleneacetic acid (ANA) 10 p.p.m. and 2,4,5-trichlorophenoxypropionic acid (2,4,5-Tp) 20 p.p.m. effectively controlled drop on Jonathan and Delicious varieties. 2,4,5-Tp retained its action much longer than ANA. 2,4,5-Tp 10 p.p.m. and alphanaphthalenacetamide 10 p.p.m. on Jonathan, and Fruitone at 8 oz./100 gal. on Delicious, in general produced results comparable with those obained with ANA.

Of the other chemicals tested on Jonathan, 2-methyl-4-chlorophenoxyacetic acid 10 p.p.m. and 2,4,-dichlorophenoxyacetic acid 10 p.p.m. were less satisfactory than ANA, while 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) 10 p.p.m. and 20 p.p.m. had no significant effect on drop.

Sprays of ANA 10 p.p.m., its amide at 10 p.p.m., and 2,4,5-Tp 20 p.p.m. on Cox's Orange Pippin, Jonathan, Granny Smith, and Sturmer, had no significant effect on the percentage of commercially sound fruit recorded after cool storage. On Gravenstein, 2,4,5-Tp 20 p.p.m. and 2,4,5-T 20 p.p.m., both of which were compared only with ANA 10 p.p.m., did not increase losses in cool store.

Introduction

Since the demonstration by Gardner *et al.* (1939) that growth substances reduced pre-harvest drop of apples, wide use has been made of sprays of chemicals such as alphanaphthaleneacetic acid (ANA) and aplhanaphthaleneacetamide (Amide). However, tests for other more effective compounds have continued. Batjer and Marth (1945) reported that 2,4-dichlorophenoxyacetic acid (2,4-D) was very effective in reducing drop of Winesap apples. Batjer and Thompson (1946) confirmed this result but found this chemical of little use on several other varieties. Edgerton and Hoffman (1951) showed that 2,4,5-trichlorophenoxypropionic acid (2,4,5-Tp) controlled drop of McIntosh apples and had a longer period of effectiveness than ANA. Since then, 2,4,5-Tp has been widely tested and found effective on a number of other apple varieties. Hoffman and Edgerton (1952) showed that 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) was as effective on McIntosh as 2,4,5-Tp.

One possible disadvantage of pre-harvest-drop sprays is their tendency to hasten ripening of fruit. With ANA and its amide, slight effects have been reported in some instances, but these have not been considered of commercial significance provided fruit is not allowed to remain on the trees past normal picking date. Reports indicate that 2,4,5-Tp may also affect maturity, especially with early varieties (Edgerton and Hoffman, 1951; Thompson, 1951).

Investigations in New Zealand on control of fruit drop and other effects of growth substances on Jonathan and Parlins Beauty apples in the Auckland district were recorded by McKenzie (1950; 1953). Since

then, further tests have been carried out at Nelson, Hawke's Bay, and Auckland, to determine the effect of several growth substances on fruit drop and on storage life of apples. An account of these experiments is given below.

Materials

Growth substances used were:

Alphanaphthaleneacetic acid (ANA), unformulated, or as Planofix.

Alphanaphthaleneacetamide, unformulated.

2,4-dichlorophenoxyacetic acid (2,4-D), unformulated.

2-methyl-4-chlorophenoxyacetic acid (MCPA), unformulated.

2,4,5-trichlorophenoxyacetic acid (2,4,5-T) as Fruitone A.

2,4,5-trichlorophenoxypropionic acid (2,4,5-Tp), unformulated or as Color-Set 1005 or as Fruitone T.

Fruitone Standard, a mixture of ANA and its amide, principally the latter.

Unformulated chemicals were dissolved in alcohol before adding to the spray tank. A spreader, Agral LN, was used with all unformulated materials.

Effect on Pre-harvest Drop

Methods

In all experiments mature trees were used, each treatment being applied to 4 or 5 trees, randomized within blocks as single-tree plots. Sprays were applied by portable orchard equipment when drop commenced. With all trials this was only a few days before the normal picking date and, for purposes of the test, fruit was allowed to remain on the trees well past this date.

After spraying, sound fruit that had been dropped from trees was counted periodically. Fruit was calculated as a percentage of the crop on the trees at the time of spraying.

Results

As weather conditions were relatively calm over the period of each experiment, fruit drop was only moderate. Details of treatments and results are given in Table 1. Cumulative totals of dropped fruit at two dates are given (i) 11 days after application, when all sprays would normally have taken effect, and (ii) after an extended period of 3-4 weeks.

Sprays of ANA and 2,4,5-Tp effectively controlled drop in all experiments. In 1952 on Delicious, and in 1955 on Jonathan, 2,4,5-Tp at 20 p.p.m., although no more effective than ANA 10 p.p.m. after 11 days, reduced drop over a much longer period. This is illustrated in Fig. 1, which shows the loss of effect of ANA and Fruitone after approximately 15 days. On Jonathan at Auckland in 1955, 2,4,5-Tp 20 p.p.m. was still controlling drop 28 days after application.

Of the other chemicals tested, Amide 10 p.p.m. and Fruitone gave results similar to ANA; MCPA 10 p.p.m. and 2,4-D 10 p.p.m. although

TABLE 1. PERCENTAGE OF FRUIT DROPPING FROM APPLE TREES SPRAYED WITH VARIOUS GROWTH SUBSTANCES

Treatment	Date of Application	Cumulative Drop			
		%	Equiv. angle	%	Equiv. angle
Jonathan, Nelson 1951		*After 11 days*		*After 24 days*	
Check		6.4	14.5	17.1	24.3
ANA 10 p.p.m.	26/3/51	1.8	7.6	6.5	14.6
Amide 10 p.p.m.	,,	2.5	9.0	7.9	16.2
MCPA 10 p.p.m.	,,	3.2	10.1	11.6	19.8
2,4,5,-Tp 10 p.p.m.	,,	3.5	10.6	6.0	14.0
2,4-D 10 p.p.m.	,,	4.0	11.4	13.6	21.4
Diff. for sig. 5%			3.1		4.2
1%			4.3		5.8
Delicious, Nelson 1952		*After 11 days*		*After 22 days*	
Check		3.6	10.3	14.4	21.6
ANA 10 p.p.m.	24/3/52	1.5	6.7	5.9	13.5
Fruitone 8 oz./100 gal.	,,	1.1	5.7	7.1	15.3
2,4,5-Tp 20 p.p.m.	,,	1.3	6.3	2.3	8.5
Diff. for sig. 5%			3.3		4.9
1%			4.6		6.8
Jonathan, Auckland 1955		*After 11 days*		*After 28 days*	
Check		9.8	17.8	17.7	24.7
ANA 10 p.p.m.	10/3/55	4.5	11.9	12.6	20.6
2,4,5-Tp 20 p.p.m.	,,	4.1	11.6	6.8	15.0
2,4,5-T 10 p.p.m.	,,	10.5	19.1	19.2	25.9
2,4,5-T 20 p.p.m.	,,	7.5	15.0	15.0	22.5
Diff. for sig. 5%			4.3		3.0
1%			5.9		4.1

significantly reducing drop after 11 days were not as effective as ANA 10 p.p.m. after 24 days; while 2,4,5-T 10 and 20 p.p.m. had no significant effect on drop.

None of the treatments caused any noticeable effects on foliage. There appeared to be no effect of sprays on colour development: all fruit however was highly coloured because of the delay in harvesting.

EFFECT ON STORAGE LIFE

Methods

Varieties tested included the early varieties Gravenstein and Cox's Orange Pippin, a mid-season variety Jonathan, and the late varieties Sturmer and Granny Smith. Storage tests were carried out with fruit from blocks separate from those used for the above pre-harvest-drop trials. Layout of blocks and treatments was similar to that described above. Sprays were applied at least 7 days before normal harvesting date. In some instances applications were made 3-4 weeks before harvesting.

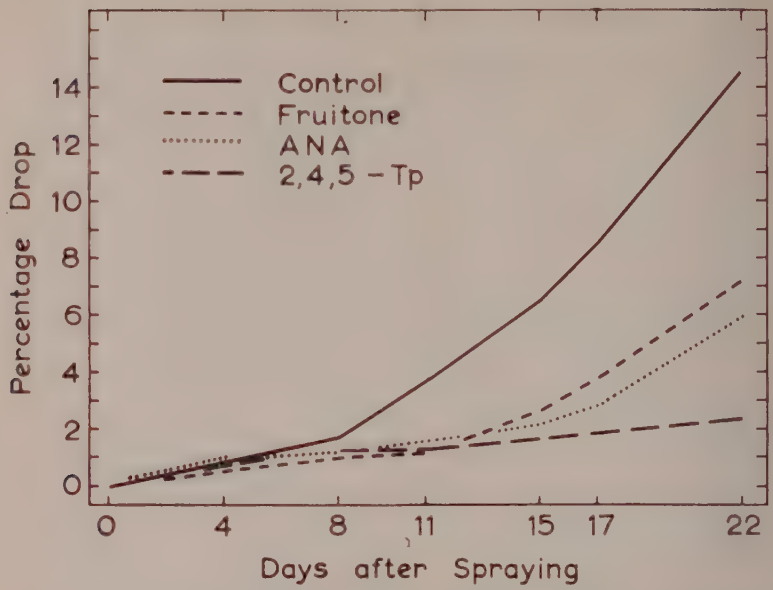


Fig. 1.—Cumulative pre-harvest drop of Delicious apples from unsprayed trees and trees sprayed with alphanaphthaleneacetic acid (ANA) 10 p.p.m., 2,4,5-trichlorophenoxypropionic acid (2,4,5-Tp) 20 p.p.m., and Fruitone 8 oz./100 gal.

A bushel case of fruit was picked at the normal harvesting date from each tree receiving treatment. All fruit was stored within 7 days of picking and held for the usual storage period of that variety. After removal from store, samples were held for 14 days at air temperature before examination.

All fruit was examined externally and in section. Disorders were recorded only when commercially significant. Fruits with a disorder of this severity in most instances would have been unmarketable or of low commercial value. General descriptions of the disorders recorded have been given by Padfield (1954).

Results

Details of treatments and results are given in Table 2.

Percentages of the main storage disorders only are given. With all varieties an insignificant number of fruits also showed other disorders. Observations at picking time showed no differences in red colour development between checks and sprayed fruit. The detailed storage examinations provided no evidence of any marked effect of the growth-substance sprays on maturity of Cox's Orange Pippin, Jonathan, Granny Smith, or Sturmer, as shown by loss in storage life under commercial conditions. On Granny Smith, Amide 10 p.p.m. significantly reduced development of coreflush. On Jonathan, the 2,4,5-Tp treatments tended to increase Jonathan spot.

Compared with ANA on Gravenstein neither 2,4,5-T or 2,4,5-Tp showed any additional storage losses.

TABLE 2. PERCENTAGE SOUND FRUIT REMAINING AFTER STORAGE AND INCIDENCE OF STORAGE DISORDERS IN APPLES FROM TREES SPRAYED WITH GROWTH SUBSTANCES

Variety		Date of Application	Date of Harvest	Length of Storage* (days)	Internal Breakdown %	Coreflush %	Wilt %	Superficial Scald %	Jonathan Spot %	Bitter Pit %	Commercially Sound %
Sturmer Hawke's Bay 1953	Check	—	31/3/53	185	9	0	12	0	0	0	81
	Amide 10 p.p.m.	24/3/53	,,	,,	10	0	5	0	0	0	85
	ANA 10 p.p.m.	,,	,,	,,	14	0	8	0	0	0	77
	2,4,5-Tp 20 p.p.m.	,,	,,	,,	9	0	8	0	0	0	83
Granny Smith Hawke's Bay 1953	Check	—	20/4/53	147	0	22	0	28	0	0	58
	Amide 10 p.p.m.	13/4/53	,,	,,	0	9†	0	35	0	0	59
	ANA 10 p.p.m.	,,	,,	,,	0	23	0	32	0	0	52
	2,4,5-Tp 20 p.p.m.	,,	,,	,,	0	21	0	39	0	0	49
Cox's Orange Pippin Nelson 1954	Check	—	26/2/54	76	17	10	1	0	0	0	81
	Amide 10 p p.m.	12/2/54	,,	,,	11	7	1	0	0	0	85
	ANA 10 p.p.m.	,,	,,	,,	9	4	1	0	0	0	86
	2,4,5-Tp 20 p.p.m.	,,	,,	,,	8	6	4	0	0	0	84
	2,4,5-Tp 20 p.p.m.	28/1/54	,,	,,	12	8	2	0	0	0	85
Jonathan Hawke's Bay 1954	Check	—	8/3/54	77	0	0	0	0	6	0	85
	Amide 10 p.p.m.	24/2/54	,,	,,	0	0	0	0	2‡	0	89
	ANA 10 p.p.m.	,,	,,	,,	0	0	0	0	6	0	84
	2,4,5-Tp 20 p.p.m.	,,	,,	,,	0	0	0	0	12	0	82
	2,4,5-Tp 20 p.p.m.	15/2/54	,,	,,	0	0	0	0	15	0	83
Gravenstein Hawke's Bay 1955	ANA 10 p.p.m.	29/12/54	20/1/55	59	2	0	0	0	0	14	78
	2,4,5-Tp 20 p.p.m.	,,	,,	,,	2	0	0	0	0	10	81
	2,4,5-T 20 p.p.m.	,,	,,	,,	1	0	0	0	0	11	85

* Includes 14 days storage at air temperature after removal from cool store.
† Significantly different from other treatments at 5% level.
‡ Significantly different from other 2,4,5-Tp at 5% level

Discussion

Results demonstrate the effectiveness of ANA, its amide, and 2,4,5-Tp in reducing pre-harvest drop of two apple varieties, Jonathan and Delicious. On Jonathan in 1951, these three chemicals at 10 p.p.m. gave similar results. A notable result with the 2,4,5-Tp 20 p.p.m. spray on Delicious and on Jonathan in 1955 was the extended period of effectiveness compared with ANA (Fig. 1), an effect originally shown by Edgerton and Hoffman (1951). In the present work, records were not continued long enough in either experiment to show the duration of effectiveness of 2,4,5-Tp 20 p.p.m., but, at least on Jonathan in 1955, good control of drop was still being obtained 28 days after application.

None of the other chemicals tested, viz, 2,4-D, 2,4,5-T, or MCPA, gave satisfactory results. Batjer and Thompson (1946) showed that 2,4-D is highly effective as a pre-harvest-drop spray on a restricted number of varieties only, and Jonathan may be outside this range.

The absence of any observed effect of growth substances on development of red colour of fruit is notable. A number of reports has shown an increase in colour following treatment with ANA (e.g. Batjer, 1942: McKenzie, 1953) and with 2,4,5-Tp (Thompson, 1951). Most of the fruit in the present tests was highly coloured, however, and it is possible that small differences may not have been detectable.

Results also showed that growth-substance sprays had no significant effect on storage life. This result with 2,4,5-Tp does not support earlier reports which indicated a considerable effect of this chemical on maturity of a number of apple varieties. Working with Gravenstein, one of the varieties used in the present experiments, Southwick *et al.* (1953) reported a marked pre-ripening of fruit with a spray of 2,4,5-Tp applied 3 weeks before harvest. Other workers since then, however, have reported no effect on maturity of a range of varieties (Batjer *et al.*, 1954; Haller, 1954). Smock *et al.* (1954) mention that variations in effect of pre-harvest growth-substance sprays on maturity in different orchards may be a result of difference in tree nitrogen status. No precise data on this point are available for the trees under test in Hawke's Bay or Nelson but all blocks could be described as being of average to good vigour.

The slight reduction of coreflush noted on Granny Smith following treatment with the amide does not agree with results obtained by Padfield (1949) who showed that Fruitone, which is principally based on amide, increased this disorder.

Results of these and similar tests have formed the basis for a published list of recommended commercial formulations for control of pre-harvest drop in apples (Bollard, 1955).

Acknowledgements

Statistical analysis of data was done by Dr. H. R. Thompson, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, Wellington.

References

Batjer, L. P. 1942: *Trans. Peninsula hort. Soc. 55:* 29-31.

Batjer, L. P.; Marth, P. C. 1945: *Science 101:* 363-4.

BATJER, L. P.; SIEGELMAN, H. W.; ROGERS, B. L.; GERHARDT, F. 1954: *Proc. Amer. Soc. hort. Sci. 64:* 215-21.

BATJER, L. P.; THOMPSON, A. H. 1946: *Ibid. 47:* 35-38.

BOLLARD, E. G. 1955: *Orchard. N.Z. 28(6):* 29.

EDGERTON, L. J.; HOFFMAN, M. B. 1951: *Proc. Amer. Soc. hort. Sci. 57:* 120-4.

GARDNER, F. E.; MARTH, P. C.; BATJER, L. P. 1939: *Science 90:* 208-9.

HALLER, M. H. 1954: *Proc. Amer. Soc. hort. Sci. 64:* 222-4.

HOFFMAN, M. B.; EDGERTON, L. J. 1952: *Ibid. 59:* 225-30.

MCKENZIE, D. W.; 1950: *N.Z. J. Sci. Tech. A31(6):* 40-46.

————1953: *Ibid. A35(1):* 45-52, 53-57, 58-62.

PADFIELD, C. A. S. 1949: *Orchard. N.Z. 22(5):* 10.

—— 1954: *N.Z. Dep. sci. industr. Res. Bull. 111:* 96 pp.

SMOCK, R. M.; EDGERTON, L. J.; HOFFMAN, M. B. 1954: *Proc. Amer. Soc. hort. Sci. 63:* 211-9.

SOUTHWICK, F. W.; DEMORANVILLE, I. E.; ANDERSON, J. F. 1953: *Ibid. 61:* 155-62.

THOMPSON, A. H. 1951: *Ibid. 58:* 57-64.

THRIPS INFESTING COCKSFOOT IN NEW ZEALAND
I. THE THRIPS FAUNA OF A COCKSFOOT SEED CROP

By K. M. Doull, Canterbury Agricultural College, Lincoln*

(Received for publication, 2 February 1956)

Summary

A study has been made of the thrips fauna of a cocksfoot seed crop at Lincoln. The most important species is *Chirothrips manicatus* Haliday, which is given the common name of "cocksfoot thrips". Observations on other species are recorded.

Introduction

Thrips have received little attention in New Zealand and the extent of the thrips fauna of the country is not known, only one native species having been described by Crawford (1941). Although thrips have been known to infest pastures and crops they have usually been regarded as unimportant and incidental inhabitants of grasses and cereals.

A study of thrips infesting cocksfoot (*Dactylis glomerata* L.) was carried out at Lincoln over the period 1953–1955 following discussions with officers of the Grasslands Division of the Department of Scientific and Industrial Research who were investigating seedsetting of cocksfoot. They found thrips in many florets and considered them to be one of the factors responsible for low seed yields of this grass.

In Europe, thrips have for many years been regarded as important pests of grasses and grains giving rise to a condition known variously as "silver-top", "bad-head", or "white-ear". Bailey (1948) surveyed the literature to that date and outlined the situation in America.

The Thrips Fauna

The thrips fauna was surprisingly large and varied. The following species were collected and identified:

	Sub-order Terebrantia.
Aeolothripidae:	*Aeolothrips fasciatus* Haliday.
Thripidae:	*Chirothrips manicatus* Haliday.
	Aptinothrips rufus Gmelin.
	Anaphothrips obscurus Muller.
	Limothrips cerealium Haliday.
	Thrips tabaci Lindeman.
	Sub-order Tubulifera.
Phlaeothripidae:	*Haplothrips niger* Osborne.

In addition, two specimens of a large apterous Tubulifera were collected in 1955. No further specimens have been found and the species has not yet been identified.

Chirothrips manicatus was found to have such a high degree of adaption to its host plant that there is every justification for giving it the common name of "cocksfoot thrips". This species was found to be responsible for a considerable reduction in seed yield and a detailed study of its biology was undertaken. This will be discussed in a subsequent paper in this series.

* Now Waite Agricultural Research Institute, Adelaide, South Australia.

The other species identified were found to be of little significance. This paper serves to record observations made on these species.

Aeolothrips fasciatus Haliday

Most winged specimens of the genus *Aeolothrips* are recognizable in the field by the two distinct white crossbands on the wings contrasting with the dark-brown body.

A. fasciatus is a predaceous species commonly found in association with other thrips, small insects, and mites. It has previously been recorded on red clover along with *H. niger* (Doull 1949). A few females were taken on cocksfoot but no males or larvae were identified. It was not common in the crops studied.

Aptinothrips rufus Gmelin

This is a cosmopolitan species found in considerable numbers throughout the whole period of the survey. It is considered to be of significance overseas, and Linnaniemi (Bailey 1948) observed a reduction in grass seed crops due to the activities of this species. Sharga (1933) has studied its biology.

A. rufus overwinters in the larval and adult stages on grass roots or at the base of the plant. Pupae were found on the foliage from October to May. Eggs are laid in slits in the foliage from September onwards. Sharga states that the whole life cycle occupies about 40 days and that the species is multivoltine. All stages may be found together during the summer, indicating that there is overlapping of the generations. No males have been found.

Adult females are apterous and pale yellow-brown, while the larvae are pale yellow to orange with head, antennae, and the last two segments of the abdomen conspicuously darker. Both adults and larvae are active, restless creatures and run rapidly over the seed heads in bright sunshine.

A. rufus could well be of some significance, for both adults and larvae are found on the seed heads before flowering. Populations over the period of this study were never very large, averaging only five thrips per seed head. Larvae were found in florets a week or more before flowering. Withered and abnormal floral parts were usually seen in florets in which thrips were found. Although there is no definite evidence to show that thrips were responsible for this damage, it is consistent with the general effect of thrips feeding on flowers. Many cocksfoot florets fail to set seed and this may be due in part to the activities of *A. rufus*.

It is not at present possible to distinguish between the damage due to *A. rufus* and that caused by *C. manicatus*, although the latter species does not appear to feed in the florets before flowering. The two insects are, however, always found together and the relative importance of each species can only be determined by further experiments from which *C. manicatus* is excluded.

Anaphothrips obscurus Muller

This species does not appear to have been recorded from New Zealand before. The identification of the species was made late in 1955 and little information is available on its biology. Adult females are

brachypterous and pale yellow, and bear a close superficial resemblance to *Aptinothrips rufus*. The main distinguishing characteristics are the eight-segmented antennae and the much abbreviated wings. Morison (1943) states that females may be both macropterous and brachypterous but no macropterous females were identified. The species was not numerous during the years of the study and made its appearance later in the year than did *A. rufus*. Larvae have not been studied, for no descriptions were available by which they could be distinguished from the larvae of *A. rufus*. This thrips may be implicated in the damage attributed to *A. rufus*.

Limothrips cerealium Haliday

This species is common in most grain-growing areas of the world, and in Europe and America, according to Sharga (1933) who studied its biology, could be responsible for the destruction of 38% of the spikelets of oats.

Adult females were found throughout the winter under the bark of trees, inside dead twigs, and in the dead stalks of cereals and grasses. The first females were taken on grasses in September or October on calm sunny days. Grasses close to shelter belts often carried quite large populations of this thrips. Dissection showed that the ovaries were immature and that the thrips were feeding on grass. They made their appearance on wheat and barley in November and the first eggs were found in wheat foliage in late November. The summer generation consists of apterous males and alate females, the larval and pupal stages having been passed on the plant.

As the wheat plants dry off and become unsuitable for feeding, mated females leave the crop and appear again on grasses. The males die after mating. The females spend a month or more on grasses before seeking out hibernation sites. The thrips was not found breeding on cocksfoot and is not implicated in any reduction of seed yield of that crop.

Thrips tabaci Lindeman

The onion thrips, *Thrips tabaci*, is a ubiquitous species and it was no surprise to encounter a few males and females on cocksfoot. No young stages were found and it can be assumed that this species does not breed on cocksfoot.

Haplothrips niger Osborne

The biology of this species in New Zealand has been discussed by Yates (1952) and Doull (1949). Its main host plant is red clover, but it also breeds on white clover, ribgrass (*Plantago lanceolata*), and plantain (*Plantago major*). No young stages were found on cocksfoot, and the few females collected are considered to be accidental visitors to the crop.

Discussion

On the basis of this survey, *C. manicatus* was the only species of importance at Lincoln during 1954 and 1955. There is no direct evidence to show that either *A. rufus* or *A. obscurus* were of any importance. It is probable, however, that both these species would be capable of reaching large populations under suitable environmental conditions. Both are active, even restless, species which might do a disproportionately great

amount of damage. No account was taken of the possible effects of thrips feeding on floral parts, but this factor may be of greater significance than it is thought to be at present. It is significant that, when cocksfoot was sprayed for a period extending from well before to well after flowering, the percentage of seed harvested was increased from 9.4 to 20.5. The implication of this will be discussed in a subsequent paper but the comment may be made here that some of this increase may have been due to reduction in the populations of *A. rufus*.

The activities of grass-infesting thrips in New Zealand require further investigation. Observations made in the course of this work indicate that the destruction of seed may be confined to a relatively few specialized species, but that the destruction of floral parts by other species may be of some significance.

ACKNOWLEDGEMENTS

Acknowledgements are gratefully made to the following: The Council of the Department of Scientific and Industrial Research for funds to carry out this work; Mr. L. Morrison for helpful guidance and criticism; Miss K. O'Neill, United States Department of Agriculture, for identification of *A. obscurus;* and Mrs. Lenie van den Bosch for much painstaking laboratory work.

REFERENCES

BAILEY, S. F. 1948: Grain and Grass Infesting Thrips. *J. econ. Ent. 41:* 702.

CRAWFORD, J. C. 1941: A New Isoneurothrips from New Zealand. *Proc. ent. Soc. Wash. 43:* 63.

DOULL, K. M. 1949: The Biology of the Red Clover Thrips. *M.Sc. Thesis.* (Deposited in Canterbury Agricultural College).

MORISON, G. D. 1943: Notes on Thysanoptera Found on Flax in the British Isles. *Ann. appl. Biol. 30:* 251.

SHARGA, U. S. 1933: Biology and Life History of *Limothrips cerealium* and *Aptinothrips rufus* Feeding on Gramineae. *Ann. appl. Biol. 20:* 308.

YATES, J. 1952: *Haplothrips niger* Osb. The Red Clover Thrips. *N.Z. J. Sci. Tech. B34:* 166.

THRIPS INFESTING COCKSFOOT IN NEW ZEALAND

II. THE BIOLOGY AND ECONOMIC IMPORTANCE OF THE COCKSFOOT THRIPS *Chirothrips manicatus* Haliday

By K. M. DOULL, Canterbury Agricultural College, Lincoln*

(Received for publication, 2 February 1956)

Summary

The biology of *Chirothrips manicatus* Haliday on cocksfoot (*Dactylis glomerata* L.) at Lincoln is described. This insect has been shown to have such a high degree of adaptation to its host plant as to warrant the common name of "cocksfoot thrips". In the crop studied, the thrips is shown to be responsible for the destruction of 30% of seed set.

INTRODUCTION

In the first paper in this series (Doull 1956) *Chirothrips manicatus* Haliday was stated to be the most important thrips associated with cocksfoot at Lincoln. The biology of this species and its economic significance have been the subject of a study carried out at Canterbury Agricultural College over the past three years. The work is not complete, but was terminated by the author's departure from New Zealand.

C. manicatus is listed by Bailey (1948) as occurring on grasses in America, but no reference is made to its importance.

There is however a confusion of identification of this species and *Chirothrips similis* Bagnall, which cannot be readily straightened out. Morison (1948) states "I found it difficult to separate Bagnall's type female of *similis* from *manicatus*". Specimens were sent to America but Miss Kellie O'Neill of the U.S. Department of Agriculture Bureau of Insect Identification reported that, although the females could not be separated from the American species of *manicatus*, the males exhibited some constant differences.

Speyer at Cheshunt has studied material from Lincoln and writes: "It is . . . best to regard Bagnall's *similis* as a synonym of *manicatus* Hal. For the present it would, in my opinion, be best to call your specimens from cocksfoot grass, *C. manicatus* Hal".

Late in the summer of 1955, specimens of female *Chirothrips* were taken from a small patch of meadow foxtail (*Alopecurus pratensis*) at Lincoln. These show some small but apparently constant differences which Speyer feels might be enough to show the presence of another species. A further collection of all stages will be made during the coming summer in an attempt to determine whether two species are in fact present in this country.

There is every possibility that a different species infests meadow foxtail. For such is the adaption of *manicatus* to cocksfoot that it seems unlikely that it could develop a similar adaptation to another host plant. Nor on the other hand does it seem likely that two different species, even closely related, would show a similar degree of adaptation to the same host plant.

* Now Waite Agricultural Research Institute, Adelaide, South Australia.

EXPERIMENTAL TECHNIQUES

No laboratory breeding has been successful, although many attempts were made. The work therefore consisted of a combination of field studies and laboratory examinations. Two cocksfoot seed crops at Lincoln College provided all material and every opportunity was taken to study the insects in the crop.

Cocksfoot shoots, and later the seed heads, were collected at random throughout the spring and summer. Material was collected from along fence lines as well as throughout the crop. Once the flower heads began to form, florets were dissected to observe the various stages of the insects and the condition of the seeds.

In an attempt to keep some seed heads free from thrips, several heads were labelled, then sprayed with DDT once a week until December when flowering was completed. The spray used was a wettable powder giving a concentration of 0.5% p.p.i. DDT. Other heads on the same plant were labelled but not sprayed, to serve as controls.

In the spring, female thrips were dissected daily to study the development of the ovaries and the correlation between maturity of the eggs and flowering of cocksfoot.

At harvest, seed heads were taken at random from the crop and fence lines, and samples of seed were taken from the header at threshing. These were dissected during the winter.

RESULTS

Thrips populations on shoots and seed heads were determined throughout the year by counts on a given number of heads. The thrips could not be induced to leave the shoots and seed heads by any of the techniques generally used, so that the samples examined each day were small. More reliable information on populations cannot be obtained until some quicker method of counting thrips has been found.

As a result of the small numbers of shoots and seed heads examined, the figures obtained do not give a reliable guide to average thrips populations. There is considerable daily variation in numbers, particularly on the seed heads. This variation is related to changes in temperature and sunlight, and populations would vary from less than one per shoot to over 100 per shoot on the following day. Numbers also varied according to the time of day, being highest in the hottest part of the day. The general impression gained from these counts is that at flowering, which is the critical time, populations were of the order of 20 per seed head.

Cocksfoot seed heads collected at harvest were examined during the winter, individual florets being dissected for examination of the condition of the seed and for the presence of thrips.

The results are presented in Table 1.

These results will be discussed later, but some explanation is needed here. The figures in Columns 1 and 2 can be considered together as can those in Columns 5 and 6, but no valid comparison can be made between the two groups since the infestation in Field B was consistently heavier than that in Field A.

TABLE 1. THRIPS POPULATIONS IN COCKSFOOT FLORETS, COLLECTED AT HARVEST, JANUARY 1955

	1	2	3	4	5	6
Per 1000 Florets	Field A Centre of Crop	Field A Fence Lines	Field A Seed from Header	Field A Cavings from Header	Field B Unsprayed	Field B Sprayed
No. of thrips	151	245	46	87	239	12
Percentage of florets containing thrips	15.1	24.5	4.6	8.7	23.9	1.2
No. of seeds	95	31	253	12	94	256
Percentage of florets containing seed	9.5	3.1	25.3	1.2	9.4	25.6

Columns 3 and 4 bear no relationship to the remainer of the table. But the total percentage of thrips in these two columns, namely 13.1, is remarkably close to the 15.1% recorded in Column 1, and does show how many of the thrips are removed from the crop at harvest. There is no true relationship between the percentage of seed in the two sets of columns, for many empty florets are blown away and do not even appear in the cavings.

THE BIOLOGY OF *Chirothrips manicatus* Hal.

Adult females overwinter in dead florets of cocksfoot. Many florets, particularly those of volunteer cocksfoot on roadsides and fence lines remain on the dead seed stalks, while others, particularly in a crop, fall to the ground. The conditions suitable for maximum survival of overwintering females have not been studied in detail. From the dissection of many florets during the winter, it seems that both excessively moist and very dry conditions are fatal. Florets that fall to the ground and remain wet for any length of time usually contain dead thrips, as do those that are stored under completely dry conditions. Florets that remain on dead seed stalks, or fall into the heart of the plant, appear to provide most suitable conditions for survival of the thrips. These florets would be exposed to sufficient moisture in rain and dew to enable the thrips to survive, but would not be exposed to continuously wet conditions even in very wet winters. The development of fungus under wet conditions might be important.

As temperatures rise in the spring, the thrips emerge from hibernation. The first thrips were found in mid September in all three seasons of study, but the main emergence from hibernation did not begin till late September or early October. The thrips at this time of the year are mainly found inside the newly emerging cocksfoot leaves or down inside the sheaths of the outside leaves. On warm sunny days they become more active and move out into the sunlight on the upper surfaces of the leaves.

The thrips feed actively at this time and dissection showed that eggs are just beginning to develop in the ovaries. As the seed heads begin to develop, thrips may be found among them, but there is little to show whether their feeding causes any damage at this time.

Thrips are ready to lay eggs by the time the cocksfoot begins to flower. The kidney-shaped, translucent eggs are laid near the top of the developing ovule, embedded to about half their length in the tissue. The first eggs are to be found in mid November on volunteer cocksfoot, which flowers earlier than the cultivated strains.

Eggs are normally laid one to a seed, but occasionally two or even three eggs may be found in one seed. It is unlikely that more than one larva could survive on one seed. Either the first larva to hatch would destroy any other eggs or all larvae would die of starvation through destruction of the seed before they had completed their growth.

The close relationship between the time of egg-laying and the condition of the floret is of interest. Eggs are never found in unfertilized florets, and this may be for one of three reasons. Many thrips are reported to require pollen in their diet before egg-laying can begin. This could be the case with *C. manicatus*, but one would expect to find eggs in unfertilized florets on a head that had begun to flower. This is not so, and there is no information to show if this thrips requires pollen before egg-laying can begin.

Another reason that can be advanced is that the thrips are unable to enter the floret until it has been forced open by the emergence of the floral parts. Certainly these thrips are rarely found in florets before flowering.

The third and most logical explanation is that eggs laid in unfertilized florets may come to nothing. Cocksfoot has very low seed-setting capacity and many florets are sterile. Young thrips will fail to survive in such florets, so it may be that the choice of only fertilized florets is an instinctive action on the part of the females.

The distribution of eggs by the females is also related to the nature of the cocksfoot seed heads on which florets are grouped together in spikelets bearing four florets. Female thrips are more likely to lay eggs in two or three florets of a spikelet, than to visit single florets in different spikelets. However it must be noted that the centre floret of cocksfoot spikelets is always sterile and no eggs were found in this floret.

The incubation period of the egg has not been accurately determined, but is apparently of the order of 5 to 7 days. Newly hatched thrips are colourless and translucent and immediately begin feeding. They are usually found head down, presumably feeding, on the base of the developing ovule. The second-stage larva is also translucent and difficult to see. It is not a typical thrips larva in that it becomes gross and bloated to such an extent that, when removed from the floret, it is unable to move. In fact, the development of the abdomen is so great that the legs of most mature larvae do not reach the surface on which they are placed. By the time the thrips has matured the seed is completely destroyed.

The first prepupae and pupae are found in the florets of volunteer cocksfoot during the first week of December and in cultivated strains

a week or so later. The larval stages therefore last about three weeks. The pupal stages appear to last only a short time, for the first new-generation adults appear on volunteer cocksfoot during the second week of December.

Pupae are colourless and translucent with bright red eyes. Towards the end of the pupal stage, body colour becomes darker as the adult form develops. The new generation consists of macropterous females and apterous males. The males on emerging leave the floret in which they have spent their larval life and crawl over the seedhead in search of females. Quite often a male will be found in a floret, resting alongside a female about to emerge from the pupal stage. Mating presumably takes place in the floret.

The males eventually die and the mated females remain in the now-dead floret where they pass the winter, emerging again in the spring to begin a new cycle. There is some indication that in volunteer cocksfoot, which flowers over a longer period, there may be a partial second generation. A few thrips of all stages may be found in seed heads on roadsides, even at the end of December, so the early-emerging females on volunteer cocksfoot may produce a partial second generation.

This thrips has been found breeding only on cocksfoot. Indeed it is unlikely to breed on other grasses, for the specific requirements of the females at egg-laying, and the feeding requirements of the larvae, must limit the choice of host plants. The need for fertilized florets for oviposition over a relatively short period limits the range of host plants to grasses that flower at this time. The larvae have particularly definite requirements. They need a large seed to nourish them, for they are obviously unable to move from one floret to another. This makes small-seeded plants such as ryegrass quite unsuitable. Other large-seeded grasses such as timothy and *Phalaris tuberosa* are also unsuitable, since their seeds have hard seed coats which the relatively weak thrips larvae cannot pierce. The only grass other than cocksfoot that is likely to be suitable is meadow foxtail, and this, as noted earlier, is heavily infested with a species of *Chirothrips* which may be a separate species.

Adults are regularly found in ryegrass and clover seed, but must be presumed to be accidental visitors. *C. manicatus,* like all thrips, is a weak-flying insect. It is sluggish except in bright sunlight on warm days. Flight takes place on calm, sunny, humid days, but wind currents carry the thrips in all directions and many of them must alight on unsuitable host plants where they remain in the absence of further suitable flying weather. They are able to fed on ryegrass and could survive until the crop is harvested in December. The mere fact that adults are present in seed samples does not mean that they breed on ryegrass and clover

The Effects of *C. manicatus* on Cocksfoot Seed Yields

The figures presented in Table 1 give a clear indication of the effects of this thrips on cocksfoot seed yields. It should be noted however that the yield of seed in 1954–55 was reduced by the dry weather experienced during spring and early summer.

Each female thrips represents one seed destroyed, for there is no evidence to show that the larvae move from floret to floret. One feature

not shown in Table 1 must be clearly understood: the seed heads were collected in December but were not examined until June, by which time the males had left the seed heads and died. No accurate count of male thrips could be made, but the impression gained was that the sexes were approximately equal. A larva that develops into a male destroys a seed in the same way as a larva that will become a female. It follows that the number of seeds destroyed should be approximately double the number of females found at harvesting. Table 2 shows the calculated effects of thrips on seed yields, based on the assumption that the sexes are equal, and using figures from Table 1 as a basis for calculation.

TABLE 2. THE CALCULATED EFFECTS OF THRIPS INFESTATION ON SEED YIELDS

	Field A	Field B Sprayed	Field B Unsprayed
Number of florets dissected	1000	1000	1000
Number of female thrips found	151	12	239
Presumed number of male thrips	151	12	239
Presumed number of seed destroyed	302	24	478
Presumed % of seed destroyed	30.2	2.4	47.8
Actual % of good seed found	9.5	20.5	9.4

It was pointed out earlier that the crop in Field B was consistently more heavily infested than that in Field A. Reasons for this will be discussed later, but the thrips infestation in Field A is possibly close to the average for many seed crops in Canterbury. There is no doubt that thrips infestation was a factor of great importance in the crops at Lincoln College in the 1954–55 season.

It is generally accepted that cocksfoot seed yields tend to decline from the second or third year after establishment. This decline is considered to be due to certain unfavourable agronomic conditions, but may in fact be due in part to increasing thrips populations. It is safe to assume that thrips populations in the first harvest season would be small and would result only from the invasion of the crop by thrips flying in from outside. In the second season the population would have increased through thrips overwintering in the crop. From then on the population would increase until a level was reached at which the insects were in equilibrium with all the various natural and mechanical factors in their environment.

The figures given in Table 2 for sprayed and unsprayed heads in the crop in Field B show quite clearly the amount of seed destroyed by thrips in Field B in 1954–55. Whereas sprayed seed heads had only 2.4% of seed destroyed, unsprayed ones on the same plants had 47.8% destroyed. Figures for percentage of good seed mean little, for although thrips infestation was reduced from 47% to 2%, a decrease of 95%, yield of good seed only increased from 9.4% to 20.5%, an increase of 53%.

Cocksfoot is particularly susceptible to variations in available moisture and the very dry conditions prevailing in the latter half of

1954 played an important part in reducing seed yields. This is borne out by seed samples examined for neighbouring farmers. One of these had only one per cent of good seed, the remainder of the seed being shrivelled through lack of moisture at the critical stage.

It is possible therefore that the 53% increase in good seed obtained by spraying represents the amount of available moisture. Although more undamaged seed was present, there was not enough moisture to fill it out. Spraying in a season of abundant moisture might yield entirely different results.

Other effects that might be expected from thrips infestation are damage to foliage and to young seed heads, or destruction of floral parts. The presence and activity of *Aptinothrips rufus* as discussed in the first paper in this series makes it difficult to say what other effects *C. manicatus* does have.

Destruction of foliage was noted in one instance only, and this was due to an abnormally large population of thrips. In the small crop in Field B, a pile of cavings and unthreshed seed heads was left in one place. Shoots taken from plants near this pile on 4 October averaged 162 thrips per shoot. Several plants round the heap were completely destroyed. Seed heads from other plants close to these cavings were examined and one thousand florets yielded only four seeds, and 46 female thrips. This may indicate that, if thrips populations are sufficiently large prior to flowering, seed yields may be much reduced through destruction of floral parts. When thrips are sufficiently active as the seed heads are developing, signs of feeding are seen on the soft young florets before they emerge from the protecting sheaths. Activity in this case means general activity during the day. It is not clear whether damage to developing florets will occur when the thrips as a result of hot sunny weather are induced to run actively all over the shoot. The reverse may be the case in that cold weather may prevent them from coming out onto the leaves and force them to wander about inside the shoots. Such damage may have occurred in 1954–55, but was obscured by frost damage following a 15° frost in October. A certain minimum level of population would be necessary before any noticeable damage would occur.

Damage to floral parts has been mentioned previously. There is little evidence to show that *C. manicatus* feeds on floral parts either before or during oviposition. *Aptinothrips rufus* is more likely to be responsible for damage to floral parts and consequent sterility to the floret, for this is a far more active species in both adult and larval stages.

Discussion

There are still several gaps in our knowledge of the biology of *C. manicatus,* but the overall picture is quite clear. The thrips shows a high degree of adaptation to its host plant. Female thrips have access to fast-growing tender young foliage in the pre-oviposition feeding period, and maturity of their ovaries coincides closely with flowering of the cocksfoot. Volunteer cocksfoot usually flowers somewhat earlier than the cultivated variety but this makes no change in the insect–plant relationship. Thrips emerge from hibernation earlier on volunteer cocksfoot so the adaptation is still complete. The large cocksfoot shoots

with comparatively loose-fitting leaf sheaths provide both food and shelter for the thrips during what must undoubtedly be a critical time in their lives.

Cocksfoot seeds are relatively large, quick to mature, and yet soft skinned over most of their growth, so that they are particularly well fitted to meet the extraordinarily high food requirements of the larvae. The overwintering thrips are provided with well sheltered sites in the tough yet light florets, which readily withstand the winter. In volunteer cocksfoot, many seed stalks remain standing throughout the winter, while the clumpy nature of the cocksfoot plant provides good shelter for those florets that do fall. In the heart of the plant they are kept off the ground and are not subjected to either excessive moisture or dryness, both of which are fatal to the thrips.

Volunteer cocksfoot along roadsides and around fence lines and shelter belts and other waste places is likely to be more heavily infested than cultivated crops. Many thrips are taken away from the crop at harvesting, but some florets fall off at or prior to harvesting, leaving sufficient thrips to continue the infestation. Volunteer cocksfoot too, with its longer flowering period, provides breeding sites for later-emerging thrips, which would otherwise be deprived of suitable oviposition sites. The thrips population on volunteer cocksfoot is likely to be in equilibrium with the environment.

The heavier infestation of the crop in Field B was due in part to the fact that it consisted of only a few rows of plants running parallel to and alongside a fence and shelter belt with a solid undergrowth of cocksfoot. There was little to prevent thrips moving from the volunteer cocksfoot to all parts of the crop. Heaps of cavings and seed heads left in the crop were also conducive to heavy infestation.

Infestation of cultivated crops each season is likely to be increased by thrips flying into the crop from volunteer cocksfoot bordering the crop. Studies on the flight habits of the thrips are needed to determine the importance of this feature.

The way in which thrips infestation is encouraged by carelessness at harvesting is shown by the very large populations on plants close to the heap of cavings in Field B. Harvesting of cocksfoot is carried out in two ways. The crop may be stooked, then stacked and later threshed from the stack; stooking and subsequent cartage to stacks always results in the loss of many florets, but many thrips must be removed from the crop by this method. When a header is used, the crop may occasionally be direct-headed, in which case most of the thrips remain in the crop. The usual practice however is to thresh from the stook. When this is done, most of the cavings and all the straw are later removed and burned.

The following figures from Table 1 show how the thrips are nearly all removed from a crop threshed from the stook:

	Thrips per 1000 Florets
Sample of seed heads from crop	151
Sample of seed from header	46
Sample of cavings from header	87
Total thrips from header	133

Only 18 thrips in each thousand florets were not recovered from the seed and cavings from the header, but this number, reinforced by migrants flying in from the fence-lines, is obviously enough to keep the infestation at a relatively high level.

Control of this thrips by spraying shows some possibilities, although field trials will be necessary to decide whether spraying will be economic. The efficiency of the spraying of individual heads is quite striking with thrips populations reduced from 47.8% to 2.4% and seed yields increased from 9% to 25%. Spraying would need to be accurately timed, but could probably be delayed until say one week before flowering, for flowering is the critical stage. The number of sprays required is not known, but probably two sprays at intervals of 10 to 14 days would be sufficient.

The average price of cocksfoot seed is about 2/6 a pound. An increase in yield of only 16 lb. of seed an acre would bring in a return of £2 per acre, which, at present costs, would probably be sufficient to cover the cost of two sprays. Since the average yield of cocksfoot is about 200 lb. of seed per acre, an increase of only 30% would raise the yield to 285 lb. per acre. Under these conditions spraying would be an economic proposition.

The destructon of seed heads of volunteer cocksfoot will go a long way towards reducing infestation in cultivated crops. Such destruction would best be done in late summer or autumn when the heads could be gathered up and burned. Destruction of volunteer cocksfoot by cutting in October would be less effective, for, although some female thrips might be destroyed, the majority would find adequate food and shelter on the remainder of the plant.

It is interesting, too, to speculate on the part played by thrips in reducing cocksfoot seed yields after the second and third seed crops. The build-up of populations of insects in perennial crops is a well established phenomenon and there is no reason to doubt that the same thing occurs in the case of *C. manicatus*. Should this be so, it reinforces the arguments in favour of regular spraying of seed crops at flowering time.

In conclusion, it must be emphasized that the discussion presented in this paper applies only to the seed crops at Lincoln College in the summer of 1954–55, which was very dry and was preceded by a mild winter. Cocksfoot is always regarded as a variable crop remarkably sensitive to variations in weather, particularly rainfall. Surveys over several seasons and in other seed-growing areas are required to establish with any degree of accuracy whether *C. manicatus* is important in other crops and other seasons. It may be that the effects of thrips become more noticeable in dry seasons and that their activities in wet years are masked by the higher yields obtained as a result of the high rainfall. It is to be expected, however, that wet weather at flowering time would inhibit the activity of thrips, which are unable to crawl about on wet foliage.

Acknowledgements

Acknowledgements are gratefully made to the following: The Council of the Department of Scientific and Industrial Research, for funds to carry out this work; Mr. L. Morrison, for helpful guidance

and criticism; Mr. E. R. Speyer of Cheshunt, England, for valuable assistance in identifying the species; and Mrs. Lenie van den Bosch, for much painstaking laboratory work.

REFERENCES

BAILEY, S. F. 1948: Grain and Grass Infesting Thrips. *J. econ. Ent. 41:* 702.

DOULL, K. M. 1956: Thrips Infesting Cocksfoot (*Dactylis glomerata*) in New Zealand. I. *N.Z. J. Sci. Tech. A38:* 52-5.

MORISON, G. D. 1948: Thysanoptera of the London Area. *Lond. Nat. Reprint 59.*

EFFECT OF STEAM AND OF SOIL DISINFECTANTS ON YIELD AND QUALITY OF NELSON GLASSHOUSE TOMATOES

By D. J. Stanton, Cawthron Institute, Nelson

(Received for publication, 9 April 1956)

Summary

Over a period of thirteen seasons, trials have been conducted with steam and different soil fumigants to ascertain their effect in the improvement of yield and quality of tomatoes in glasshouses belonging to the Cawthron Institute.

Steam treatment of the soils resulted in great benefit to the growth of tomato plants and yield of fruit which in several tests was more than double that of unsterilized plots with the same manurial treatment.

Among the fumigants tested, chloropicrin and a mixture of chloropicrin with DD were outstanding in the beneficial effects resulting from their use. With these fumigants the yield and quality of tomatoes was equal to that obtained from steam treatment of the plots.

Chlorobromopropene, and DD used by itself, gave satisfactory results in the first season of the tests, but the continued use of these fumigants on the same plots failed to maintain the high yields characteristic of steam or chloropicrin treatments of the plots.

Under the conditions of the experiments, formalin and Sterizal did not prove very satisfactory in the treatment of glasshouse soil.

Introduction

Glasshouse tomatoes have been grown in Nelson as a commercial crop for more than 60 years. As long ago as 1922, many instances of poor growth of tomato plants with accompanying low yield of fruit had occurred in Nelson tomato houses. The early experiments[1] of Messrs. Vitetta Bros. and the Cawthron Institute demonstrated the great value of steam in the treatment of glasshouse soils, yield of tomatoes in certain tests being raised from 2.3 lb. to 6.3 lb. per plant. Certain chemicals were tested by the Institute at this time, and of these carbon disulphide gave the best result with a yield of 5.6 lb. per plant. Toluene carbolic acid, formalin, bleaching powder, and dinitrochlorbenzene gave some improvement in growth of tomato plants but were inferior in their effect to either steam or carbon disulphide treatment of the soils. As a result of the remarkable effect of steam in the treatment of glasshouse soil, the majority of Nelson tomato growers adopted it as an annual practice.

Since the adoption of steam sterilization in the 1920s, the growth of tomato plants and yield of fruit has been very satisfactory but the quality of fruit appeared to deteriorate. Blotchy ripening, locally known as Cloud, was one of the noticeable defects in the fruit. With a view to overcoming this defect and improving the quality of Nelson crops, the Institute recommenced tomato investigation in 1942. These investigations have included the effect of steaming and soil fumigants on yield and quality of tomatoes, a study of physiological disorders of tomatoes, and the effect of fertilizers and management factors on yield and quality of fruit. In this paper, the effect of steam and soil fumigants on yield and quality of tomatoes is reported.

EXPERIMENTAL

Cultural Treatments

The glasshouses in which the present trials have been conducted are situated on an alluvial clay loam with a structure and profile very suitable for tomato culture. The area has been consistently used for glasshouse and outdoor tomato culture for some fifty years.

The two glasshouses used for the trials are each 90 ft. in length and 22 ft. and 30 ft. respectively in width. The houses were not heated. Plants were set out in the ground in mid August. Harvesting covered the period from late November until early March. Cultural operations conformed with local procedure for the production of a commercial crop.

Experimental plots in glasshouse A were 8½ sq. yd. and were planted with 27 plants. In house B, the plots were 16 ⅔ sq. yd. and were planted with 52 plants. This gave a density of approximately 15,000 to the acre.

Owing to the satisfactory pH and exchangeable-base status of the soil, no lime or magnesium compounds have been applied. Organic matter has been maintained by the incorporation each season of partly decomposed clover straw. Further details of the nutrient status of the soil, the climatic conditions, and the earlier fertilizer programme have been reported previously[2, 3].

Although basic fertilizer programmes and cultural operations have been altered over the years, they were uniform over all plots recorded in each season. In the last two seasons the fertilizer application was as follows:

3 parts 44/46 superphosphate,
3 parts muriate of potash,
1 part dried blood,
1 part sulphate of ammonia,
1 part nitrate of soda,

applied:

(a) along trenches before planting at 4½ oz. per sq. yd.
(b) topdressed early October at 9 oz. per sq. yd.
(c) topdressed early November at 9 oz. per sq. yd.
(d) topdressed early December at 4½ oz. per sq. yd.

No fertilizer was applied before soil-sterilizing treatment.

Water was given at uniform rates to all plots except in the two final seasons when fumigant-treated plots received supplementary water in the early part of the season. Further comment on watering will be made later.

Potentate has been the variety grown since 1948, prior to which Dreadnought was used.

Sterilization Treatments

Steam. Treatment was carried out by local contractors. The harrow apparatus[4] with tines 12 to 14 in. in length was used. Steam at 100 lb. per sq. inch boiler pressure was passed for 5 minutes per grid. Tine

holes were sealed and the area covered with sacks. Soil temperature 30 minutes later was 180°F.

Formalin. One pint of 40% formalin diluted in 5 gal. water was applied to each square yard of soil. After saturation of the soil with the solution, plots were loosely covered with building paper or damp sacks for three days. Sterizal and fumigant plots were covered in a similar way.

Sterizal. A proprietary phenol-xylenol emulsion was used at 1% dilution at the rate of nine gallons per sq. yd.

Chloropicrin. This was injected at a depth of six inches. Until the 1949–50 season the rate of application was 4 ml. per sq. ft.; from 1950 the rate was 3 ml. Soil temperatures at time of fumigant applications have always been low, between 50°F. and 55°F.

Dichloropropane-dichloropropene (DD). Injection was made as for chloropicrin. In the 1947–48 season this was at 5 ml. per sq. ft., in the 1948–49 season at two rates, 5 ml. and 3 ml. per sq. ft. In the last five seasons the lower rate only has been used.

Chloropicrin plus DD. This was used as a mixture of equal volumes. The mixture was applied at 3 ml. per sq. ft.

Chlorobromopropene (CBP). Injection was made as for other fumigants at the rate of 3 ml. per sq. ft.

Soil treatments were carried out seven to ten weeks prior to planting the tomatoes.

The soil sterilization trials were conducted in conjunction with other nutritional and cultural studies. In tabulating comparisons, the plots listed are those on which correlated cultural and nutritional practices were used. Wherever possible, plots have been restricted to those on which a particular sterilizing treatment has been repeated over a succession of years. For example, although a number of plots were left untreated at different times, only one plot was maintained in that condition over a prolonged period (9 years). Untreated plot records are therefore from one plot only. In all cases supplementary plots were in good agreement with the series presented.

Steam-plot figures have been taken from three replications for each season; other treatments are from duplicated plots.

Results

Seasonal climatic conditions and the construction and dimensions of glasshouses influence yield. Crops must therefore be compared within a single house and for a particular season. For the two houses, over the period of the trial, the relative efficiency of the treatments in maintaining yield was consistent.

Yields, expressed as pounds per plant, from the plots under various treatments during the thirteen-year period are shown in Table 1.

Steaming was the only treatment carried out continuously throughout the thirteen-year period. Other sterilizing agents were on trial for periods ranging between two and ten years.

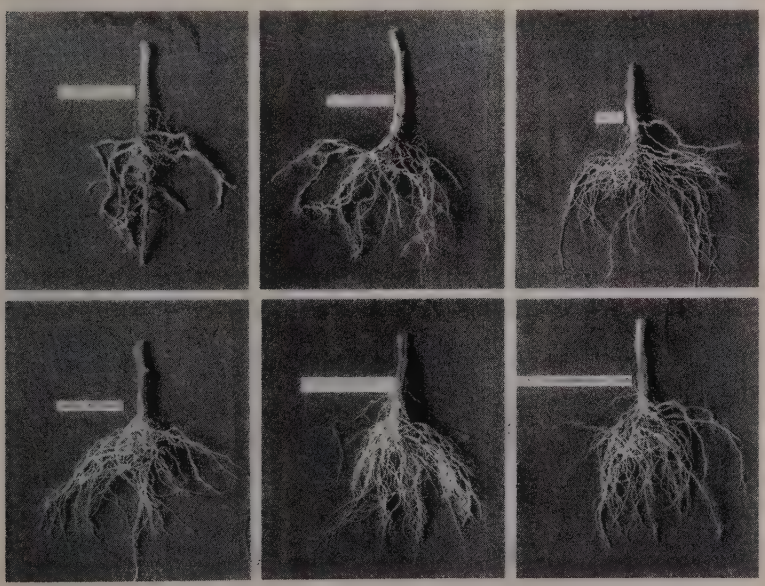
Annual steam sterlilization of soils may greatly affect structure. Rapid destruction of organic material may occur. Clay soils that are over-wet or over-dry at steaming may become sticky, or brick-like clods may be formed. Even under favourable conditions steaming still induces these tendencies. Unsterilized plots maintain a more friable and open structure, especially in the presence of sufficient organic matter.

All plots treated with fumigants for several successive seasons remain much more friable and permeable, and applied water drains away more quickly. Moisture determinations have shown that these plots are consistently one to two per cent lower in moisture content than the steamed soil.

In comparison with steam, plots under continuous fumigant treatment have shown indications that the plants benefit from increased rates of watering early in the season. In 1953–54 and 1954–55 all fumigant plots were given additional water when they appeared to require it. From Tables 1, 3, and 4, this procedure appears to have been beneficial in slightly improving yield of chloropicrin, and chloropicrin plus DD plots, without adversely affecting fruit quality.

In Tables 2 to 7, direct comparisons between pairs of treatments are shown for the maximum periods during which plots were grown under similar conditions.

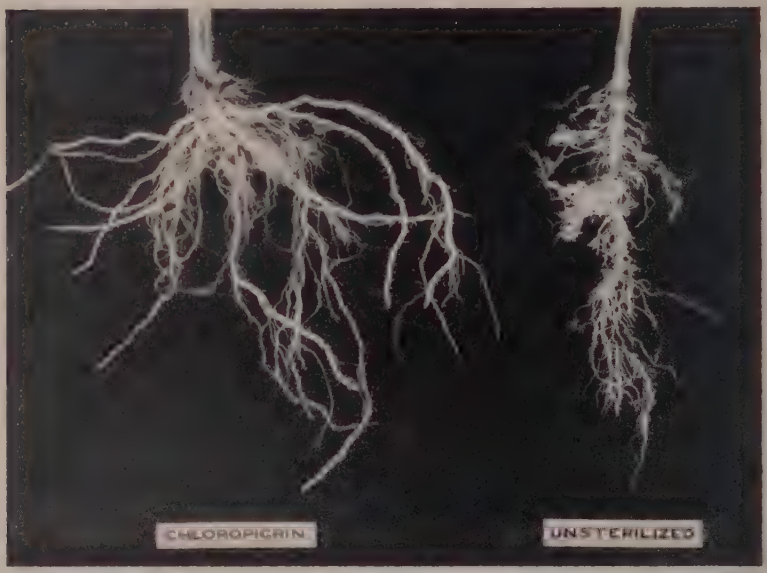
Since the 1947–48 season all fruit has been graded in three classes. First grade comprises all fruit of desirable size, regular shape, good texture, free from scars, blemishes, and physiological disorders. Second grade consists of marketable fruit with minor defects.



—*Photo. R. Blick.*

Fig. 1.—Typical root systems of tomato plants with different soil treatments.

At the end of each season, roots of all plants were removed and compared. Even at this late stage there was usually close association between health and vigour of the root system and growth and appearance of the plants (see Figs. 1 and 2 for typical roots with different soil treatments .



—*Photo. R. Blick.*

Fig. 2.—Comparison of root systems of tomato plants: unsterilized and with chloropicrin soil treatment.

The comparative efficiency of soil treatments had no effect on diseases of aerial parts of the plants. Although *Cladosporium* was troublesome in some years, and less frequently *Botrytis* and virus mosaic, these diseases have not varied in severity from treatment to treatment. Where a whole glasshouse is subjected to a particular soil treatment, air-borne diseases may be considerably influenced by the method adopted.

The relative effectiveness of the treatments as shown by yields was also apparent in the health and vigour of the plant growth.

Unsterilized and Steamed Plots

In Table 2, comparison over a ten-year period is made between unsterilized plots and steam-treated plots. Untreated plots showed poor growth and low yields in the first crop following discontinuation of steam treatment; subsequent crops tended to deteriorate slowly but progressively. In 1942–43, yield was 68% of that from steam; in 1951–52 it reached a minimum of 34%. The average yield for the ten-year period was 56% of that from steamed plots.

TABLE 1. AVERAGE YIELD IN POUNDS PER PLANT FROM GLASSHOUSE PLOTS TREATED WITH STEAM, SOIL DISINFECTANTS, OR SOIL FUMIGANTS

House and Season	No Treatment	Steam	Chloropicrin	Chloropicrin + DD	DD	CBP	Formalin	Sterizal
A 1942/43	5.4 (1)	8.0 (1)						
A 1943/44	5.2 (1)	8.7 (1)						
A 1944/45	4.9 (2)	7.7 (2)					6.3 (1)	
A 1945/46	4.6 (3)	7.4 (3)					5.5 (2)	
A 1946/47	4.8 (4)	9.0 (4)	8.4 (1)					
B 1946/47	6.5 (1)	10.0 (1)	9.7 (1)				7.6 (1)	
A 1947/48	3.8 (5)	7.3 (5)	7.4 (2)				5.8 (1)	
B 1947/48	4.9 (2)	7.5 (2)	7.9 (2)		7.4 (1)			
A 1948/49	5.2 (6)	8.5 (6)	8.6 (3)		8.2 (1)			
A 1949/50	4.5 (7)	9.6 (7)	8.6 (4)		8.2 (2)			6.0 (1)
A 1950/51	4.1 (8)	9.5 (8)	10.0 (5)	9.3 (1)	9.5 (3)			6.4 (2)
A 1951/52	3.2 (9)	9.5 (9)	9.7 (6)	9.7 (2)	7.6 (4)	9.1 (1)		
A 1952/53		8.5 (10)	8.7 (7)	8.4 (3)	7.0 (5)			
A 1953/54		9.4 (11)	10.3 (8)*	10.4 (4)*	7.3 (6)*	9.0 (1)*		
A 1954/55		10.6 (12)	10.8 (9)*	11.0 (5)*				
AZ 1953/54			11.5 (1)*			8.5 (1)*		
AZ 1954/55			14.4 (2)*			11.1 (2)*		

Figures in parenthesis are the number of consecutive seasons of the treatment. Plants in AZ plots were spaced at 12,000 per acre compared with 15,000 in all other plots.

* These plots received additional water in early part of season.

TABLE 2. YIELD AND FRUIT QUALITY ON UNSTERILIZED AND STEAMED PLOTS OVER TEN SEASONS

House and Season	Unsterilized				Steam			
	Yield lb. plant	Percentage			Yield lb. plant	Percentage		
		1st	2nd	Reject		1st	2nd	Reject
A 1942/43	5.4				8.0			
A 1943/44	5.2				8.7			
A 1944/45	4.9				7.7			
A 1945/46	4.6				7.4			
A 1946/47	4.8				9.0			
B 1946/47	6.5				10.0			
A 1947/48	3.8	34	54	12	7.3	26	50	24
B 1947/48	4.9	16	54	30	7.5	26	53	21
A 1948/49	5.2	49	25	26	8.5	39	20	41
A 1949/50	4.5	49	44	7	9.6	37	50	13
A 1950/51	4.1	64	32	4	9.5	55	39	6
A 1951/52	3.2	68	28	4	9.5	38	50	12
Average	4.8	47	39	14	8.6	37	44	19

TABLE 3. YIELD AND FRUIT QUALITY ON STEAM AND CHLOROPICRIN PLOTS OVER NINE SEASONS

House and Season	Steam				Chloropicrin			
	Yield lb. plant	Percentage			Yield lb. plant	Percentage		
		1st.	2nd.	Reject		1st.	2nd.	Reject
A 1946/47	9.0				8.4			
B 1946/47	10.0				9.7			
A 1947/48	7.3	26	50	24	7.4	27	56	17
B 1947/48	7.5	26	53	21	7.9	27	50	23
A 1948/49	8.5	39	20	41	8.6	40	23	37
A 1949/50	9.6	37	50	13	8.6	45	45	10
A 1950/51	9.5	55	39	6	10.0	52	41	7
A 1951/52	9.5	38	50	12	9.7	51	40	9
A 1952/53	8.5	48	47	5	8.7	55	42	3
A 1953/54	9.4	57	39	4	10.3*	56	40	4
A 1954/55	10.6	67	32	1	10.8*	63	36	1
Average	9.0	44	42	14	9.1	46	42	12

* Chloropicrin plots given supplementary water in early part of season.

TABLE 4. YIELD AND FRUIT QUALITY ON CHLOROPICRIN AND CHLOROPICRIN PLUS DD PLOTS OVER FIVE SEASONS

House and Season	Chloropicrin				Chloropicrin plus DD			
	Yield lb. plant	Percentage			Yield lb. plant	Percentage		
		1st.	2nd.	Reject		1st.	2nd.	Reject
A 1950/51	10.0	52	41	7	9.3	50	43	7
A 1951/52	9.7	51	40	9	9.7	54	39	7
A 1952/53	8.7	55	42	3	8.4	51	45	4
A 1953/54	10.3	56	40	4	10.4	53	44	3
A 1954/55	10.8	63	36	1	11.0	60	38	2
Average	9.9	55	40	5	9.8	54	42	4

TABLE 5. YIELD AND FRUIT QUALITY ON CHLOROPICRIN AND DD PLOTS OVER SEVEN SEASONS

House and Season	Chloropicrin				DD			
	Yield lb. plant	Percentage			Yield lb. plant	Percentage		
		1st.	2nd.	Reject		1st.	2nd.	Reject
B 1947/48	7.9	27	50	23	7.4	23	49	28
A 1948/49	8.6	40	23	37	8.4	41	25	34
A 1949/50	8.6	45	45	10	8.2	38	52	10
A 1950/51	10.0	52	41	7	9.5	54	40	6
A 1951/52	9.7	51	40	9	7.6	48	46	6
A 1952/53	8.7	55	42	3	7.0	54	42	4
A 1953/54	10.3	56	40	4	7.3	53	40	7
Average	9.1	47	40	13	7.9	44	42	14

TABLE 6. YIELD AND FRUIT QUALITY ON CHLOROPICRIN AND CHLOROBROMOPROPENE PLOTS IN THREE SEASONS

House and Season	Chloropicrin				Chlorobromopropene			
	Yield lb. plant	Percentage			Yield lb. plant	Percentage		
		1st.	2nd.	Reject		1st.	2nd.	Reject
A 1951/52	9.7	51	40	9	9.1	39	52	9
A 1953/54	10.3	56	40	4	9.0	54	41	5
AZ 1953/54	11.5	50	45	5	8.5	54	39	7
AZ 1954/55	14.4	76	23	1	11.1	75	24	1
Average	11.5	58	37	5	9.4	56	39	5

Over a period of five years, the percentage of first-grade fruit was appreciably higher from unsterilized plots, 47% compared with 37% from steamed plots. The actual weight of first-grade fruit was less, however, because of reduced total yield. Unsterilized plots tended to be free from blotchy ripening, steam plots often showed high incidence.

On unsterilized plots growth was weak and stunted. Fruit size and quantity were small. Wilt symptoms were general, although early death of plants was infrequent. On unsterilized plots, roots were sparse, with little fibrous growth; they were brown in colour, contorted, and much subject to lesions and decay. Root-knots of eelworm were very seldom seen.

On steam plots, plants were always healthy and strong-growing. In earlier stages, precautions were necessary to avoid excessive vegetative

TABLE 7. YIELD FROM FORMALIN AND STERIZAL TREATMENTS IN COMPARISON WITH UNSTERILIZED AND STEAMED PLOTS FOR CORRESPONDING SEASONS

House and Season	Formalin lb. plant	Unsterilized lb. plant	Steam lb. plant
A 1944/45	6.3*	4.9	7.7
A 1945/46	5.5*	4.6	7.4
B 1946/47	7.6*	6.5	10.0
A 1947/48	5.8	3.8	7.3
Average	6.3	5.0	8.1
House and Season	**Sterizal lb. plant**	**Unsterilized lb. plant**	**Steam lb. plant**
A 1949/50	6.0	4.5	9.6
A 1950/51	6.4	4.1	9.5
Average	6.2	4.3	9.6

* Single plots only.

growth. Towards the end of the season, too late to affect yield, plants often showed mild symptoms of wilt diseases. On removal, roots were found usually to be clean, white, and healthy, with good development of fibrous roots.

Steam and Chloropicrin

These two treatments are compared in Table 3. There were only minor differences in yield in any season. Averaged over a nine-year period, both treatments gave almost identical yields, 9.0 and 9.1 lb., per plant. Fruit quality was also equally good. Incidence of blotchy ripening was consistently less on chloropicrin plots.

Chloropicrin and Chloropicrin plus DD

These two treatments were compared over five seasons. Results are set out in Table 4. Seasonal differences were small and average yields about the same, 9.9 and 9.8 lb. per plant. Fruit quality and incidence of blotchy ripening was not influenced by treatments.

On chloropicrin plus DD plots, plants were healthy. With repeated use of the fumigants on the same plot, growth was less rank, and plants were surdier and firmer than with steam. Roots were clean, white, and healthy. Plants were less susceptible to mild wilt symptoms late in the season than on steam-treated plots. No eelworm root-knots were seen.

On chloropicrin plots, as with chloropicrin plus DD, plant growth was steady and healthy. The plants also showed less mild wilt symptoms than on steamed plots. Eelworm (*Heterodera*) was always present

on these plots; even from the first season of treatment with chloropicrin a large and variable proportion of plants developed root-knots, and on some plants infestation was heavy, but the infestation was apparently innocuous. Infested plants could not be detected before removal, and showed no deleterious symptoms; the root system of infested plants was usually more extensive and fibrous root-development greater; apart from root-knots the root system was white and clean. Only mild and infrequent infestation has been seen on plants from other treatments, including unsterilizezd plots.

Chloropicrin and DD

Comparisons were available over seven seasons (Table 5). Treatment was repeated on duplicated DD plots for six consecutive seasons. Following steam, the first and second years of DD treatment resulted in very satisfactory yields. Deterioration appeared with the continued use of this fumigant on the plots. In the sixth consecutive season, yield from DD was 7.3 lb. per plant, chloropicrin (8th season) 10.3 lb. The appearance of the fruit was similar on these two treatments. In several instances an unpleasant flavour was noticed in fruit grown on DD plots. High rates of injection, low soil temperatures, and high soil moisture at time of application appeared conducive to this condition. This tendency to off-flavour can be reduced by injecting in drier and warmer soil, and by ample aeration to release fumigant residues before planting.

DD has not proved so effective in controlling fungous diseases as steam, chloropicrin, or chloropicrin plus DD. Following steam, for one or perhaps two seasons, it has justified its use by maintaining yields and plant growth. Even then, in the latter part of the season, plants usually showed serious to mild symptoms of wilts. With repeated applications, earliness of appearance and severity of these diseases increased. Root development was fairly satisfactory. Increasing severity of fungous infection was associated with intensified light-brownish discolouration of roots and greater development of lesions and decay.

Chloropicrin and Chlorobromopropene (CBP)

Chlorobromopropene, a bromine derivative of DD, was on trial in three seasons (Table 6). In 1951–52, CBP followed Sterizal (6.4 lb. 1950–51 Table 1) and resulted in a yield of 9.1 lb. per plant, only slightly below steam (9.5 lb.) or chloropicrin (9.7 lb.) in that season.

CBP was used again on these plots in 1953–54, chloropicrin being used in the interim when CBP was not available. The yield of 9.0 lb. per plant again compared favourably with steam (9.4 lb.) but was lower than chloropicrin (10.3 lb.).

In 1953–54, a previously uncropped and unsterilized area became available at the end of the glasshouse. Four plots were laid out with chloropicrin and CBP treatments. Spacing between rows was greater on these plots and yields per plant correspondingly higher than on older-established areas. Over two seasons, these plots (AZ, Tables 1 and 6) showed a superiority of chloropicrin over CBP treatments.

Results averaged from the three seasons showed definite lowering of yield on CBP plots, 9.4 lb. per plant in comparison with chloropicrin 11.5 lb. Plots with CBP and DD treatments were never available for comparison in the same season. Both materials tended to show similar characteristics in their effect on growth and yield.

On chlorobromopropene plots, plant growth and appearance of roots resembled that from DD plots. Chlorobromopropene may prove somewhat superior to DD but these two materials were not used under comparable conditions in the same season.

Formalin and Sterizal

In Table 7, yields from formalin (4 seasons) and Sterizal (2 seasons are shown in comparison with steamed and untreated plots over the respective periods. Although both materials gave some improvement over unsterilized areas, they were much inferior to steam treatment. With formalin, average yields were 6.3 lb. per plant compared with steam 8.1 lb. and unsterilized 5.0 lb. per plant. In comparison with Sterizal 6.2 lb., steam plots yielded 9.6 lb. and unsterilized 4.3 lb. per plant.

Plants on both formalin and Sterizal plots, although superior to those on unsterilized plots, did not establish readily. Symptoms of root infection appeared early and became fairly severe. Roots were sparse, with few fibrous roots, and resembled those from unsterilized plots. There was browning, some lesions, and decay.

DISCUSSION

Over the duration of these trials, improved cultural and nutritional practices have tended to raise total yields, although seasonal conditions and outbreaks of aerially transmitted diseases have caused fluctuations.

It should be noted that soil temperatures (about 50° F.) when fumigants were applied approached the minimum temperature recommended. Despite this, very satisfactory results were obtained from their use. Yields equivalent to, or better than, those from steam treatment resulted from the use of chloropicrin and from chloropicrin mixed in equal volumes with DD.

Chlorobromopropene and DD alone gave less satisfactory yields, and their control of fungous diseases was less effective. They had good insecticidal properties. There were indications that they might be used as alternatives to steam for a season or two without serious deterioration in yield. Further trials are desirable with CBP.

Formalin and Sterizal are applied with large volumes of water, and, on soils of heavy texture, soil structure may be harmed. Some disease organisms were not adequately controlled. Although yields were greater than from unsterilized plots, the increase is not likely to repay the cost of treatment.

The most desirable treatment for use against soil-borne pests and diseases depends on a number of practical considerations:

(a) the types of organism present,

(b) convenience in applying treatment,

(c) weed control,

(d) capital outlay and costs of materials and labour.

Steam will normally control all diseases and eliminate weeds, although the presence of organisms at depths in excess of fifteen inches may reduce the efficiency of the harrow method; and also there may

be reinfestation of the upper steamed soil. The Hoddeston-pipe method facilitates steaming at greater depths. Steam plant requires considerable capital investment, and operating costs are high. When conducted by contractors, arranging convenient times for treatment or attaining access to properties may entail problems.

Fumigants will vary in effectiveness according to conditions of the soil, its type and structure, soil temperatures and soil moisture, types of organisms present, and the chemical employed. Very little capital outlay is involved. Materials and labour costs are usually considerably less. Treatment may be applied at the time most suitable to the grower. Against this there is less satisfactory control of weed growth.

ACKNOWLEDGEMENT

The assistance and co-operation given by Mr. G. F. Woods throughout the period of these trials is gratefully acknowledged.

REFERENCES

1. RIGG, T. 1924: *N.Z. Fruitgrower and Apiarist. 6:* 625-31.

2. KIDSON, E. B.; WATSON, J.; HODGSON, L. 1953: *N.Z. J. Sci. Tech. A. 35:* 127-34.

3. KIDSON, E. B.; STANTON, D. J. 1953: *N.Z. J. Sci. Tech. A. 34:* 521-30.

4. ATKINSON, J. D.; BRIEN, R. M.; CHAMBERLAIN, E. E.; COTTIER, W.; JACKS, H.; REID, W. D.; TAYLOR, G. G. 1949: Tomato Diseases and Pests in New Zealand and their Control. *N.Z. Dep. sci. industr. Res. Inf. Ser. Bull. 2.*

THE RATE OF GROWTH OF SHORT-ROTATION-RYEGRASS PASTURES IN THE LATE AUTUMN, WINTER, AND EARLY SPRING

By R. W. BROUGHAM, Grasslands Division, Department of Scientific and Industrial Research, Palmerston North

(Received for publication, 1 February 1956)

Summary

The rate of growth in pastures of short-rotation ryegrass and clover, which were spelled from grazing at four different times during the late autumn and early winter, was determined by measuring their curves of growth following each spelling date.

Three distinct phases of growth were obtained from the pastures of the first three spelling dates. Initially the rate of growth increased. This was followed by a phase in which the growth rate remained constant after which it declined and finally became negligible.

The growth curve obtained from the pasture closed on the fourth spelling date showed only the initial phase of growth.

Closing early in the autumn gave a higher maximum rate of growth and a higher maximum yield of herbage. As time of spelling was delayed however, the growth rate and maximum yields decreased. It is considered that these were determined by the lower temperatures and shorter day lengths together with the increased death of plant tissue that occurred during the later weeks of the experiment.

A significant feature of the results was that during the experimental period, the weekly increment in total growth was never much lower than 200 lb. D.M. per acre for pasture at its most favourable stage of growth.

The implications of the results on grass production over the late autumn, winter, and early spring are discussed.

INTRODUCTION

A number of factors militate against grass production over the late autumn, winter, and early spring. Most of these are determined directly or indirectly by low temperatures and short day lengths, and result in a marked reduction in the growth rate of pasture species.

The *in situ* conservation of pasture herbage grown during the late autumn and early winter, for feeding in the late winter or early spring, is now a feature of pasture husbandry in New Zealand. The practice, which was first advocated by Marryat (1938) and Riddett (1938), aims at supplementing the limited grass growth of winter and early spring in order to meet the high livestock feed requirements normal at that season in New Zealand because of spring calving and lambing (McMeekan, 1945; Levy and Sears, 1948).

On most New Zealand farms where the practice has been adopted, the pastures have been dominantly perennial ryegrass and white clover associations. Perennial ryegrass does not grow as much during the winter as short-rotation ryegrass (*Lolium perenne* x *L. multiflorum*) (Corkill, 1945; Mitchell, 1954). Because of its capacity for winter growth, this latter strain of ryegrass is well suited to the above practice. The aim of this study was to obtain information on the rate of growth of a pasture of short-rotation ryegrass and clover under long spelling or

resting during the late autumn and winter and to determine the influence of time of commencement and duration of spelling on the rate of growth.

EXPERIMENTAL

A field experiment was laid down at Palmerston North, on Manawatu silt loam. The field had been sown in the autumn of 1953 with a mixture of short-rotation ryegrass, red clover, and white clover. At the commencement of the experiment in the autumn of 1954, the pasture was producing 60% ryegrass, 25% to 30% clover and 10% to 15% other grasses (mainly *Poa* spp.) and weed species (mainly *Rumex* spp.).

Approximately three weeks before the commencement of the experiment an area of 3 ch. × 1 ch. was divided into four equal areas of ¾ ch. × 1 ch. These latter were subsequently treated as separate "fields" and were defoliated at least twice at three-weekly intervals before the commencement of each treatment. The first of these defoliations was achieved by grazing but subsequent defoliations were made with a sickle-bar mower to prevent uneven regrowth. Immediately before the commencement of each treatment the pasture was mown to a height of 1 in. and the herbage removed. This procedure was adopted to obtain uniform pasture at similar stage of growth at the commencement of each period of spelling. It was considered that the removal of this herbage without equivalent return of manure would have little effect on subsequent growth. This supposition was strengthened by the fact that no visible symptoms of nitrogen deficiency in the grass growth were apparent over the experimental period.

The main experimental treatments were four dates of commencement of spelling from grazing, during autumn and winter.

Following the final preparatory defoliation of each "field", three randomized blocks of nine plots were laid out. Each plot was 15 ft. × 4 ft. and was cut only once during the experimental period. In each block, herbage was cut and measured from plots at successive stages of growth.

The first spelling started on 1 April 1954, and succeeding spellings started at three-weekly intervals. The final measurements of all treatments were made on 5 August 1954.

Table 1 shows the cutting scheme.

Yields were determined by cutting a 3-ft. strip through the length of each plot. The herbage was cut down to 1 in., the height at the commencement of the experiment. The cut herbage from each plot was then mixed and samples were taken for dry-matter determinations and herbage analyses.

The weather records (Fig. 1) are from the meteorological station situated approximately 800 yd. from the experimental site. This station conforms to the requirements of the N.Z. Meteorological Service (*N.Z. Meteorological Office Circular No. 18, June 1943*).

RESULTS

Table 2 shows the mean yields of ryegrass, clover, and total herbage at each stage of growth from each spelling date. The yields are expressed in lb. dry matter per acre.

TABLE 1. DATE OF SPELLING AND SUBSEQUENT CUTTINGS OF PLOTS

Date	Week No.	Treatments Spelling Date			
		1	2	3	4
		1 April	22 April	13 May	3 June
1 April	0	Closed			
8 ..	1	Cut			
15 ..	2	Cut			
22 ..	3	Cut	Closed		
29 ..	4		Cut		
6 May	5	Cut	Cut		
13 ..	6		Cut	Closed	
20 ..	7	Cut		Cut	
27 ..	8		Cut	Cut	
3 June	9	Cut		Cut	Closed
10 ..	10		Cut	Cut	Cut
17 ..	11			Cut	Cut
24 ..	12	Cut	Cut	Cut	Cut
1 July	13				Cut
8 ..	14		Cut	Cut	Cut
15 ..	15	Cut			Cut
22 ..	16		Cut	Cut	Cut
29 ..	17				Cut
5 August	18	Cut	Cut	Cut	Cut

The logistic equation $W = \frac{A}{1 + Be^{-Ct}}$ * was fitted to the above data by an iterative procedure, "weighting" the squared observations according to the inverses of variances of the observations. Fig. 1 shows the fitted curves for total herbage and ryegrass yields, and also the weekly averages of the mean daily temperatures and the weekly rainfall totals.

The logistic equation fitted to the data in this experiment is based on the differential equation $\frac{dw}{dt} = KW(A-W)$. This equation expresses the idea that biological growth is described by two simultaneous laws. The first of these is the Exponential (or Logarithmic) law that rate of growth is proportional to weight (W) at any instant (t). The second is the Mitscherlich law, that rate of growth is proportional to

* In this equation, W = weight at any instant, t = time and A, B, and C are parameters to be determined.

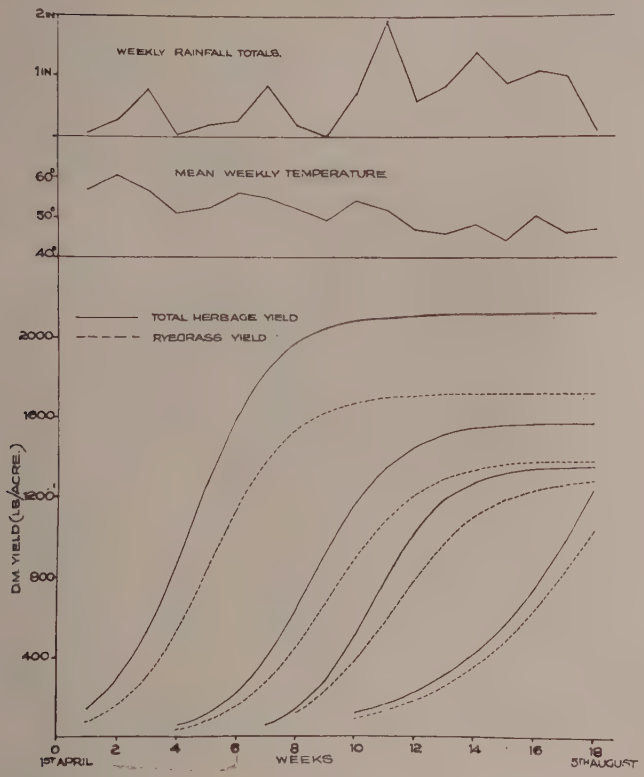


Fig. 1.—Fitted logistic curves for total herbage and ryegrass yields (lb. D.M./ac.) for the four dates of spelling. Also the mean weekly air temperatures and weekly rainfall totals for the experimental period.

the difference between the weight at the instant considered and the maximum weight that can be attained in a given set of environmental conditions.

The growth curve derived from the differential equation is sigmoid, reaching an asymptote at $W = A$, and having a maximum rate of increase of $\frac{dw}{dt} = \frac{1}{4} AC$ when $t = \frac{\log_e B}{C}$, the weight attained at that time being $W = \frac{1}{2}A$.

It should be noted that as growth recorded was that above a base height, this yield is given initially as zero, but the fitted logistic has an initial value corresponding to the amount of herbage left at topping.

The parameters of the fitted curves and the deductions made from the curves for total herbage and ryegrass yields are shown in Table 3.

Data supplementary to those obtained in this experiment are shown in Fig. 2. These data were obtained for the years 1948–55 from pastures of short-rotation ryegrass and white clover on a nearby area that had

TABLE 2. MEAN YIELDS OF TOTAL HERBAGE, RYEGRASS, AND CLOVER (LB. D.M. PER ACRE), AT THE VARIOUS STAGES OF GROWTH*

Week No.	Treatment 1 1 April			Treatment 2 22 April			Treatment 3 13 May			Treatment 4 3 June		
	Total	Rye-grass	Clover	Total	Rye-grass	Clover	Total	Rye-grass	Clover	Total	Rye-grass	Clover
0												
1	88	50	22									
2	298	160	97									
3	673	455	152	—	—	—						
4				48	32	11						
5	1142	788	252	121	72	39						
6				237	170	50	—	—	—			
7	1833	1367	318				81	56	20			
8				655	448	146	119	98	12			
9	2259	1689	441				300	256	31	—	—	—
10				1194	950	144	694	543	96	122	92	17
11							745	565	96	156	120	18
12	1981	1618	232	1323	1092	115	794	627	118	221	180	22
13										294	240	24
14				1497	1246	82	1336	1209	51	484	399	32
15	2023	1801	114							566	480	24
16				1510	1316	82	1384	1234	55	726	628	46
17										924	802	60
18	2007	1334	57	1825	1645	25	1478	1282	61	1268	1079	52

* Yields of unsown species are not shown.

TABLE 3. PARAMETERS OF FITTED CURVES AND DEDUCTIONS OBTAINED FROM THE CURVES

	Treatment					
	1		2		3	
	Total	Ryegrass	Total	Ryegrass	Total	Ryegrass
A	2120	1725	1577	1383	1357	1289
B	28.3	42.0	50.9	61.9	47.9	34.6
C	0.75	0.73	0.71	0.67	0.83	0.66
Max growth rate (lb./wk.)	396	316	280	233	283	214
Time to max. rate (wks.)	4.5	5.1	5.5	6.1	4.6	5.4
Yield when max. rate is reached	1060	863	789	692	679	649
Maximum yield	2120	1725	1577	1383	1357	1298

Note.—In Treatment 4 the maximum growth rate was not reached.

been managed for several years as a self-contained sheep-farming unit. They are total herbage D.M. yields obtained by using the cage measurement technique (Sears 1951). Individual measurements from this sheep-farming unit are plotted about the curves which were fitted to

the data obtained in the present experiment. Each point about the appropriate curve was obtained from pasture that was spelled for the time shown and closed within a range of three days on either side of the spelling dates in the present experiment.

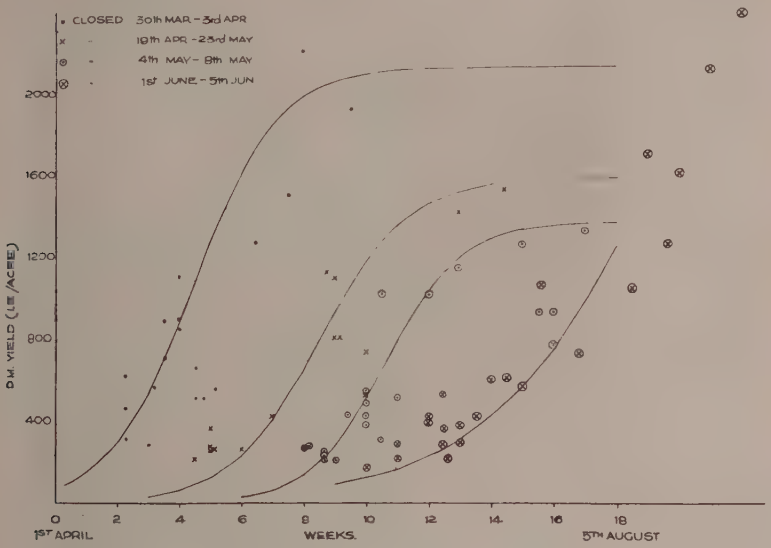


Fig. 2.—The supplementary data plotted (as lb. D.M. per acre) about the fitted logistic curves of the experimental data.

The measurement technique used in collecting the above data was designed to measure utilized D.M. Consequently the amount of herbage left after cutting was determined by the height to which the pastures were actually grazed. The height varied from about $\frac{1}{2}$ in. to 3 in. and should be compared with the constant cutting height of 1 in. in the reported experiment. This would account for some of the variability of the supplementary data when plotted about the fitted curves of the experimental data, but would not outweigh seasonal variability as the main cause.

Discussion

In a previous study (Brougham 1955), the curve of growth, based on D.M. yields, of a similar type of pasture, was shown to be sigmoid and of a form in accordance with the Exponential and Mitscherlich laws. An explanation of this pattern of growth was given in terms of the inherent properties of the plants and the operation of environmental factors. In the present study, the growth curves were of the same general form and the fitting of logistic curves to the data appeared justified.

Three phases of growth were distinguished in the previous study and a number of factors were considered as determinants of these phases. The results of the present experiment can be explained in a similar way although some of the factors limiting growth were different.

Initially, regardless of spelling date, there were increases in the weekly D.M. increments of total herbage and of ryegrass. Table 2 and Fig. 1 also show a trend towards an increase in the duration of this phase of growth. For treatment 1, the time period was approximately 4.5 weeks for total yield and 5.0 weeks for ryegrass, whereas for treatment 4 the weekly increments in both total and ryegrass yields were still increasing after nine weeks from spelling. Compared with these results obtained in winter, the duration of the first growth phase in spring (Brougham 1955) was much shorter, seldom exceeding three weeks. The factors considered as determinants of this phase of growth in the previous study probably operated similarly in this experiment.

The increasing duration of the first growth phase in the present experiment is explicable in terms of growth responses to temperature and day length. Fig. 1 shows that the mean weekly temperature decreased gradually, although irregularly, from the first week of the experiment (56.4°F.) to the 14th week (44.3°F.), after which it began to increase. Day length and also intensity of light decreased over this period, and therefore total light decreased greatly. The effects of variations in these factors on the rate and pattern of tissue formation in ryegrass has been demonstrated by Mitchell (1954). His work suggests that in the present field experiment the falling temperatures and the diminishing radiant energy in early winter caused a reduction in rates of tillering and of tissue formation on individual ryegrass tillers. After each spelling date there would therefore be an increase in the time taken to reach the stage when the ground cover by leaves was sufficient to ensure maximum photosynthetic activity. It is probable that, as the light intensity diminished with the approach of mid-winter, maximum photosynthetic activity was achieved with a progressively smaller amount of foliage. This would account for the fact that the amount of herbage produced up to the end of the first growth phase diminished with successive spelling dates. The anomalous behaviour of treatment 4 during the last three to four weeks was probably due to increasing day length, greater light intensity, and rising temperatures.

The second growth phase is characterized by an approximately constant rate of increase in dry matter. After each of the first three spelling dates, this phase lasted about three weeks for both ryegrass and total herbage yields. The highest rate of growth was obtained when the pasture was closed early. As shown in Table 3, the weekly increment in total D.M. under treatment 1 was about 400 lb. per acre but only 280 lb. per acre under treatment 3. These results should be compared with the weekly increment of about 1,000 lb. of D.M. per acre obtained in the spring (Brougham 1955).

A final phase during which the net increments of D.M. became progressively less and finally negligible was evident in all treatments except the last. Over the winter, precipitation exceeds evapotranspiration and the resultant moist conditions in the bottom layers of the pasture provide a favourable environment for organisms such as slugs, worms, and fungi, all of which destroy plant tissue. That there was a loss of herbage is evident from Table 2, where decreases in clover yields during the final phases of growth are shown in treatments 1 to 3 inclusive. Decomposition of ryegrass leaves was also observed, but these losses were apparently offset by the formation of new tissue.

During this last phase of growth, yield maxima of both ryegrass and total herbage were highest for the earliest spelling date and decreased progressively for successive treatments. It is of interest to note that the maximum yield of approximately 2,000 lb. D.M. per acre for treatment 1 was only about one-third of that obtained in the spring (Brougham 1955). This progressive decrease in yield maxima is attributed to an increase in tissue deterioration due to increased rainfall (Fig. 1).

Although no visible evidence of nitrogen deficiency was observed, it is considered possible that maximum yields were determined in some degree by available nitrogen supply. Heavy rains may have leached away soluble nitrogen, and the low temperatures probably reduced the rate of mineralization of organic nitrogen.

The experiment was carried out during one season only, and it is fully realized that the results obtained could have only limited applicability. However, the supplementary data shown in Fig. 2 give supporting evidence for a period of eight years, and it is considered that some discussion on pasture management over the late autumn, winter, and early spring is warranted. Obviously such a discussion will apply only to areas in which climatic conditions do not differ markedly from those pertaining to this experiment, and to ryegrass-clover pastures in which short-rotation ryegrass, with its winter-growth characteristics (Corkill 1945), is the dominant component.

The outstanding features of the results are the effect of long spelling on yield maxima and rate of growth of short-rotation-ryegrass pastures over the winter. Fig. 1 shows that a negligible increase in total yield was obtained from the 9th to the 18th week from pasture closed on 1 April after a yield of approximately 2,000 lb. D.M. per acre was reached. For the same period, pasture closed on the 9th week (3 June) yielded about 1,200 lb. D.M. per acre. The resulting loss of D.M. production from long spelling during this period is therefore considerable. Of equal importance to this loss of feed are the detrimental effects of intense inter-species and intra-species competition, resulting in a thinning-out of clovers and grasses followed by low subsequent herbage yields due to poor nitrogen nutrition. This has been demonstrated under practical farm conditions by Long (1947).

The growth potential of short-rotation-ryegrass pastures during the winter is well illustrated in the second phase of growth. The weekly D.M. increment was never much lower than 200 lb. D.M. per week. This growth rate would easily meet the winter maintenance requirements of one dairy cow per acre (Wallace 1955), if the herbage produced could be fully utilized. In practice, more particularly on heavy soil types, stock trampling and fouling often prevent full utilization, but by various methods of rationed grazing these difficulties can be minimized (Riddett 1951, Sears 1955).

The results suggest that maximum production of herbage would be obtained from a grazing system in which the spelling interval was never much in excess of 6 weeks. Such a system would enable a good balance to be maintained between the grasses and clovers and thus ensure vigorous growth in the early spring. Lenient grazings would reduce the duration of the first growth period so that most of the growth between grazings would occur at the maximum rate.

This is illustrated in Table 4, where estimated yields of available D.M. from different systems of grazing have been computed from Fig. 1.

TABLE 4. ESTIMATED GRASS YIELDS FROM DIFFERENT GRAZING SYSTEMS OVER LATE AUTUMN AND WINTER (computed from Fig. 1)*

Grazing System			Est. Yield (lb. D.M./ac.)	Est. Av. D.M. Production per Week (lb./ac.)
Height of Defoliation	Number of Grazings	Interval between Successive Grazings (weeks)		
1 in.	1	18	2120	118
..	2	3 — 15	2100	117
..	3	3 — 3 — 12	2100	117
..	4	3 — 3 — 3 — 9	2270	126
..	3	3 — 6 — 9	2690	149
..	2	6 — 12	2960	164
..	2	9 — 9	3290	183
3 to 4 in.	3	5 — 5 — 6	3620	226

* For all but the last estimated system the date of spelling would be 1 April. The spelling date of the last system would be 2 weeks later.

The most highly productive grazing system of those shown in this table is that in which neither long spelling nor hard grazings occur, i.e., the system in which there would be three equal growth periods over the last 16 weeks of the experimental period. It is estimated that this system would produce an average of 20% to 25% more growth per week than any other system, with an average weekly D.M. increment of about 220 lb. per acre.

ACKNOWLEDGEMENTS

The writer is grateful to Prof. W. Riddett for permission to use the experimental area on the Massey College Dairy Farm, and to Dr. P. D. Sears, Grasslands Division, Palmerston North, for permission to use the supplementary data shown in Fig. 2. The assistance of Mr. A. C. Glenday, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, with the mathematical treatment of the results is also much appreciated.

REFERENCES

BROUGHAM, R. W. 1955: A Study in Rate of Pasture Growth. *Aust. J. agric. Res. 6(6):* 804-12.

CORKILL, L. 1945: Short Rotation Ryegrass, its Breeding and Characteristics. *N.Z. J. Agric. 71:* 465-8.

LEVY, E. B.; SEARS, P. D. 1948: Special Purpose Pastures in Intensive Grassland Farming. *Proc. 8th annu. Conf. N.Z. Soc. Anim. Prod.* pp. 72-85.

LONG, W. S. 1947: Intensive Grassland Production on a Dairy Farm. *Proc. 9th Conf. N.Z. Grassl. Ass.* pp. 40-3.

MCMEEKAN, C. P. 1945: "Principles of Animal Production". 243 pp. Whitcombe & Tombs, Christchurch, N.Z.

MARRYATT, E. R. 1938: Cheap Insurance against Feed-flavour, Bloat, and Late Spring. *N.Z. J. Agric. 56:* 323-5.

MITCHELL, K. J. 1954: Influence of Light and Temperature on Growth of Ryegrass (*Lolium* spp.). III. Pattern and Rate of Tissue Formation. *Physiol. Plant. 7:* 51-65.

———1954: Growth of Pasture Species. I. Short Rotation and Perennial Ryegrass. *N.Z. J. Sci. Tech A36:* 193-206.

RIDDETT, W. M. 1938: The Relation of Pasture Species to Quantity and Quality of Milk. *Proc. 7th Conf. N.Z. Grassl. Ass.*

———1951: Advantages of Rationed Grazing. *Proc. 6th annu. Meet. Dairyfmrs. Massey agric. Coll.* pp. 75-83.

SEARS, P. D. 1951: The Technique of Pasture Measurement. *N.Z. J. Sci. Tech. A33(1):* 1-29.

———1955: The Management of High Production Pasture. *Proc. Canterbury agric. Coll. annu. Fmrs. Meet.*

WALLACE, L. R. 1955: Meeting the Seasonal Requirements of the Dairy Herd. *Proc. Ruakura Fmrs. Conf. Week.* pp. 213-4.

GOITROGENIC EFFECT OF WHITE CLOVER (*Trifolium repens* L.)

By D. S. Flux,[1] G. W. Butler,[2] June M. Johnson,[2] A. C. Glenday,[2] and G. B. Petersen[3]

Plant Chemistry Laboratory, Department of Scientific and Industrial Research and Massey Agricultural College, Palmerston North

(Received for publication, 10 January 1956)

Summary

(1) The possibility that the cyanogenetic glucosides present in certified white clover could produce a goitrogenic effect in animals has been tested. Two feeding experiments with rats and guinea-pigs were carried out; in each case groups of animals received cyanogenetic and non-cyanogenetic white clover respectively.

(2) In the guinea-pig-feeding experiment, measurements of thyroid cell heights, total thyroid iodine, and incorporation of ^{131}I into the thyroid showed that a goitrogenic factor was present in cyanogenetic white clover. The levels of thiocyanate in the sera of the two groups of animals indicated that thiocyanate was probably the goitrogenic factor.

(3) In the rat-feeding experiment, similar uptake curves of ^{131}I and levels of serum thiocyanate to those shown by the guinea-pigs were obtained.

(4) In a sheep-feeding experiment it was shown that the level of thiocyanate in the sera of animals fed cyanogenetic clover could rise to concentrations similar to those associated with goitrogenic effects in rats and guinea-pigs.

(5) From experiments with normal rats injected with potassium thiocyanate it was shown that levels of serum thiocyanate encountered in the feeding experiments could have a direct depressing effect on thyroid gland activity as evidenced by incorporation of ^{131}I.

Introduction

The strains of white clover most widely used in New Zealand contain the cyanogenetic glucosides lotaustralin and linamarin (Corkill, 1940, 1942; Melville and Doak, 1940). The agronomic merit of the strains is measured by their cyanide content.* The toxicity to sheep of the cyanide released from this material has been investigated by Coop and Blakley (1949) who found that, although intakes of cyanide by grazing sheep could be high under some circumstances, the rate of detoxication by conversion to thiocyanate was rapid enough to prevent cyanide poisoning from developing.

Thiocyanate is known, however, to be goitrogenic in that it inhibits thyroidal accumulation of iodine (Barker *et al.*, 1941; Astwood, 1943; Rawson *et al.*, 1944; Wolf *et al.*, 1946; Brown-Grant and Gibson, 1955). Consequently it seemed important to ascertain whether the thyroid gland function of animals eating clover containing cyanogenetic glucosides

1. Physiologist, Department of Dairy Husbandry, Massey Agricultural College, Palmerston North.

2. Biochemist, Chemist, and Biometrician respectively, at Plant Chemistry Laboratory, Palmerston North.

3. Present Address: Dept. of Biochemistry, University of Oxford, England.

* Cyanogenetic and non-cyanogenetic white clover will be referred to as CN clover and non-CN clover respectively.

was adversely affected. Care (1954) has suggested that fat-lamb production might be affected by this factor. In the first experiments this possibility was investigated in guinea pigs and rats. Subsequent experiments were directed towards finding serum levels of thiocyanate necessary to affect thyroid gland activity in rats. A sheep-feeding experiment was also carried out to determine the levels of serum thiocyanate likely to occur in the field.

EXPERIMENTAL

Guinea-pig Feeding Experiment

The guinea-pigs used were random-bred animals which had been weaned shortly before the experiment started. Both males and females were included in each group but the sexes were caged separately. For convenience, three animals on the same treatment were housed in each cage. Animals were allotted at random to treatment groups, the proportion of males to females being the same in each group at the start of the experiment.

Details of the animals' initial body weights were as follows:

Treatment Group	No.	Mean Initial Body Weight, g.
Fed non-CN clover	15	185 ± 5.7
Fed CN clover	14*	189 ± 5.9

* One animal died from a cause not connected with the experiment.

The small difference in body weight was not significant.

The strains of clover used were Ac 52 (non-CN) and Ac 50, 51 (CN), as described by Corkill (1952). The guinea-pigs were fed fresh clover each morning for 46 days. Care was taken not to include too large a proportion of petioles, which contain little or no cyanogenetic glucoside (Melville *et al.* 1940). Samples of the fresh material and any clover remaining uneaten were taken for dry-matter determinations and further samples of leaves of the two clover types were tested qualitatively for cyanide content using a picric acid test (Melville *et al.*, 1940) to check that no contamination of the clover plots had occurred. These tests showed that the degree of contamination of the material fed with clover of the wrong strain was very low indeed.

Over the experimental feeding period the average dry-matter consumption of the guinea-pigs fed the CN clover was 15.5 g. and that of the guinea-pigs fed the non-CN clover, 14.5 g. per day. Efforts were made to keep the food intake similar and as the non-CN clover was more palatable the amounts of it fed were restricted. The dry-matter content of the non-CN clover was often higher than that of the CN clover, and, despite frequent adjustments of amounts fed, the guinea-pigs on the non-CN clover diet had the higher dry-matter intake.

Measurement of Incorporation of ^{131}I

The guinea-pigs were fasted for 12 hours prior to dosage with ^{131}I to reduce the risk of death under ether anaesthesia. The labelled iodide

was injected intraperitoneally in doses of 28.7 μC in 0.8 μg. of carrier iodide. The time-course of incorporation of ^{131}I iodide into the thyroid was then followed for a period of 30 h. This dosage rate does not induce histopathological changes (Goldberg *et al.*, 1950). The animals were lightly anaesthetized with ether during the counting operations. They were held in a readily reproducible position over a perspex block which fitted inside the lower jawbone, so that the thyroid gland was situated directly above the end-window of the detecting Geiger-Muller tube. A 2-cm. thickness of lead sheet shielded the tube from radiation from the bodies of the animals, a hole of 2.5 cm. diameter being drilled in the lead between the perspex block and end-window of the counting tube.

Counting was carried out over periods of 2 min., during which time 700 to 1500 counts were observed. The detector was a GM4 tube with a background count of 45 counts per min., and the counter a scale-of-two model made by Wellington Electronics Ltd.

Chemical Analyses

At the conclusion of the ^{131}I experiment, the animals were killed and the thyroids dissected out for determination of total thyroid iodine and for histological examination. Whole blood was collected for determination of the final level of thiocyanate.

Thiocyanate was determined colorimetrically on the deproteinized serum by the method of Fister (1950), the principle being the formation of ferric thiocyanate.

Total thyroid iodine determinations were made on one lobe of each gland, the method used being essentially that of Taurog and Chaikoff (1946) with the modification that the iodine was distilled off over a 20-min. period instead of the 7-min. period recommended.

Total iodine in the clover feeds was also determined by the above method, with modifications as detailed in another communication (Johnson and Butler, in preparation).

Cyanogenetic glucosides in the two strains of white clover were determined by the method of Sullivan (1939).

Thyroid Cell Heights

One lobe of each thyroid was sectioned for determination of acinar cell heights. Preliminary tests showed that fixation in 5% acetic acid Zenker's solution and paraffin embedding by the dioxan technique resulted in no appreciable shrinkage in the overall dimensions of guinea-pig thyroids. The sections (4μ) from each thyroid were mounted and stained with phosphotungstic acid haematoxylin (Cowdry, 1948).

After preliminary measurements of the heights of cells in follicles selected randomly, an efficient scheme for selection of cells was set up. This involved selection of cells within follicles, follicles within sections, and sections within thyroids, by a method of randomization restricted so that cells from the same follicle would not be measured on more than one occasion.

Rat Feeding Experiment

The rats were from the colony kept at the Animal Research Station, Wallaceville, N.Z., these being derived from the Wister strain.

Both sexes were used, with males and females randomly distributed through the treatments; the animals were approximately 6 weeks old and there were 6 animals in each treatment. The diet was changed gradually from one of grain meal and dried butter-milk powder to one consisting of 80% ground freeze-dried white clover (of the same types as used in the guinea-pig feeding experiment) and 20% of the meal mixture. The feeding of this latter diet was continued for 10 days prior to injection of ^{131}I.

Measurement of Incorporation of ^{131}I into Thyroids

The same method of injection, light anaesthetization, and counting as was described for the guinea-pig feeding experiment was employed. 20 μC ^{131}I iodine was injected intraperitoneally; no carrier iodide was present since this could have upset the iodine balance of the animals. The animals were not fasted prior to or during the experiment and the period of recording incorporation of ^{131}I into the thyroids was 4 to 5 hours. Counting was carried out over periods of two mins., 500–1,000 counts being observed. A lead cathode tube Pb G10 (Twentieth Century Electronic), shielded from the light and having a background of 75 counts per min., was used as detector.

The measurement of serum thiocyanate and of the levels of total iodine and cyanogenetic glucosides in the freeze-dried clovers was carried out using the same methods as in the guinea-pig feeding experiment.

Thiocyanate Injection Experiments

Rats were again obtained from the Animal Research Station, Wallaceville, and were approximately six weeks old at the time of the experiments. In this experiment only female rats, spayed to eliminate the possibility of interference from endogenous oestrogen (Noach 1955a, b), were used. They were maintained on a pelleted mixture of grain meal and dried skim-milk powder to which a vitamin-A supplement was added.

Potassium thiocyanate solutions of varying strengths were injected subcutaneously in volumes up to 1 ml., $\frac{1}{2}$ to 1 h. prior to the injection of radio-iodide; the control animals received an injection of the same volume of distilled water. The counting technique was identical with that described for the rat feeding experiment, with the exception that a predetermined count of 2048 was made. The animals each received a dose of 20 μC ^{131}I iodide containing 0.15 μg. I as carrier.

Tap water was available to all animals at all times and the temperature of the animal house was kept above 65°F.

Sheep Feeding Experiment

In order to investigate the levels of serum thiocyanate likely to be encountered in the field, the fluctuations in the levels of thiocyanate in the sera of four sheep were followed over a period of two months. The animals were stall-fed on a clover diet for 50 days; two animals received non-CN red clover throughout, while the other two received red clover for 8 days, followed by CN white clover for 32 days and then by red clover for 10 days. Finally all four animals were starved for 4 days.

The animals were bled from the ear vein, approximately 15 ml. of whole blood being collected at intervals of 3 or 4 days. The thiocyanate analyses were carried out on 5 ml. of serum, without duplication, using the method described earlier.

RESULTS

Clover Analyses

The levels of iodine and cyanogenetic glucoside found in the two strains of white clover are shown in Table 1. It will be seen that the CN clover contained a markedly higher level of iodine than the non-CN clover.

TABLE 1. LEVELS OF IODINE AND CYANOGENETIC GLUCOSIDE (EXPRESSED AS CN) IN THE TWO STRAINS OF WHITE CLOVER

Clover	I Content (μg./100 g. D.W.)		CN Content (mg. CN/100 g. D.W.)	
	Guinea-pig Feeding Exp.	Rat Feeding Exp.	Guinea-pig Feeding Exp.	Rat Feeding Exp.
Non-CN	5.0	2.0	25.8	0.0
CN	68.4	28.4	129	144

Guinea-pig Feeding Experiment

In Table 2 are shown the mean serum thiocyanate levels for a sample of guinea-pigs selected at random from each treatment group, the mean thyroid follicle cell heights for all animals, and the mean total thyroid iodine levels for one lobe of each thyroid for the animals in each group. These figures show that the mean thiocyanate level of the sera of the guinea-pigs fed the CN clover was clearly higher than that of the controls, the difference being significant at the 0.1% level. Despite the fact that the non-CN clover contained no cyanide, the analysis of the blood of the control guinea-pigs showed a level of 6.4 mg. SCN per 100 ml. serum.

TABLE 2. MEAN BLOOD THIOCYANATES, MEAN THYROID FOLLICLE CELL HEIGHTS, AND MEAN TOTAL THYROID IODINE LEVELS FOR GUINEA-PIG FEEDING EXPERIMENT

Clover Fed	Serum Thiocyanate (mg. SCN/100 ml. serum)		Height of Thyroid Follicular Cells (μ)		Thyroid I Levels (μg./lobe)
	No. of Guinea-pigs	Mean ± S.E.	No. of Guinea-pigs	Mean ± S.E.	Mean ± S.E.
Non-CN	7	6.4 ± 0.3	12*	6.57 ± 0.23	0.86 ± 0.25
CN	8	13.1 ± 0.3	14	7.60 ± 0.22	0.33 ± 0.22

* During the experiment three guinea-pigs in this group died, reducing the number to 12.

The mean total iodine content of the thyroids of the guinea-pigs fed CN clover was significantly lower than that of the animals fed non-CN clover.

The mean cell height of the thyroid follicular cells was greater in the guinea-pigs fed CN clover, the difference being highly significant. Considerable variation between the heights of cells within follicles, and between means for follicles, means for sections, and means for thyroids within treatment groups was found. Because these data are of interest for planning sampling methods, the results of the analysis of variance are shown in Table 3. The source of the greatest amount of variance

TABLE 3. ANALYSIS OF VARIANCE OF THYROID CELL HEIGHT DATA

Source of Variation	d.f.	Mean Squares	Variance Components as Percentage of Total Variance
Clover treatments	1	150.89	11.9
Animals within treatments	24	15.64	10.7
Sections within thyroids	130	5.48	15.5
Follicles within sections	156	3.04	15.5
Cells within follicles	623	1.82	46.3

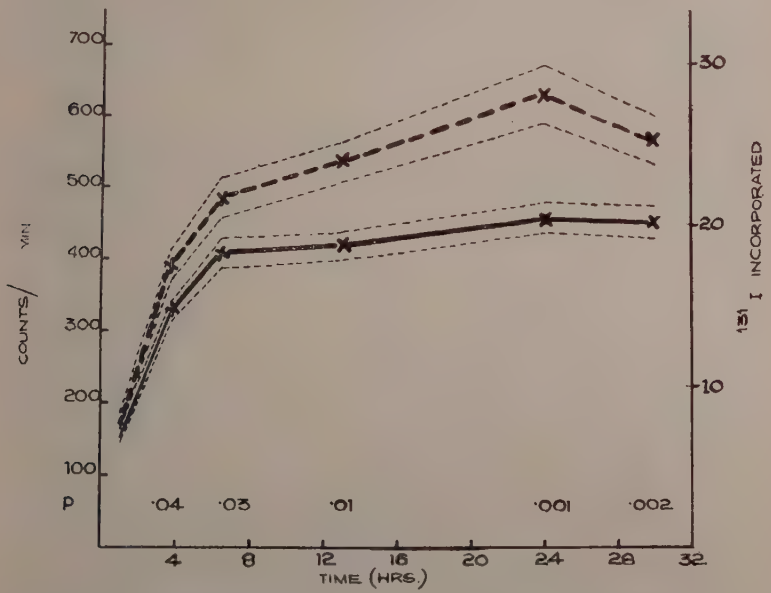


Fig. 1.—Levels of ^{131}I activity of the thyroids of guinea-pigs fed CN and non-CN clover, at various times after ^{131}I injection. Full line: animals fed non-CN clover. Dashed line: animals fed CN clover. Dotted lines are drawn one standard error each side.

was differences between cells within follicles; other sources of variation were of much less importance and were all similar in their contributions to the total variance.

Incorporation of ^{131}I into Thyroids

In Fig. 1 is shown the ^{131}I activity in the thyroids of the guinea-pigs fed the two strains of white clover at different times after injection. As counts were made at the same time for all animals, the rate of change was assumed to be constant over any time interval between counts, and the data were obtained for the graph by interpolation. The times taken were as close to the average times of inspection of the thyroids as possible. Mean counts and their standard errors were plotted, and the results of tests of significance of differences between treatment means are shown on the graph.

The average rate of uptake of ^{131}I did not differ significantly over the first hour or so, but from then until about 24 h. the ^{131}I content of the thyroids of the guinea-pigs fed CN clover increased faster than that of the controls, and as it did so the level of significance of the difference increased. The apparent decline after 24 h. in the ^{131}I content of the thyroids of the guinea-pigs fed the CN clover (but not of those fed non-CN clover) was not significant.

Linear regressions were fitted to all data between 6.50 and 24 h. and gave:

Non-CN clover group $= +2.30 \pm 1.52$ counts per h. (sig. 10% level).

CN clover group $= +5.87 \pm 3.22$ counts per h. (sig. 10% level).

The lack of a significant difference in the slopes of the regression lines was undoubtedly due to greater variation in the treated groups.

Body Growth

The average body-weight gain of the guinea-pigs fed the non-CN clover over the 46 days was 88 ± 5.4 g. and of those fed CN clover, 85 ± 5.4 g. This small difference was not significant. The average dry-matter intakes were 14.5 and 15.5 g. per day for the non-CN and CN clovers respectively.

Rat Feeding Experiment

The levels of ^{131}I in the thyroid glands of the rats fed the two strains of clover at different times after injection are shown in Fig. 2. The same form of interpolation was used as in the guinea-pig data. Except for the shorter time-scale and the fact that the animals fed the CN clover did not show any fall over the last period during which counts were made, the picture is very similar to that for the guinea-pigs fed fresh clover.

Over the first 0.5 h. after injection, the thyroid ^{131}I contents did not differ significantly but from about 0.5 h. onwards the difference between groups became more apparent, the thyroids of the control rats showing lower counts.

Linear regression lines were fitted to all data within each group after 0.5 h. For the control rats the slope was 4.22 ± 5.6 counts per min. per h. (not significant) and for those fed CN clover, $+ 25.6 \pm 7.2$ counts per min. per h. (highly significant).

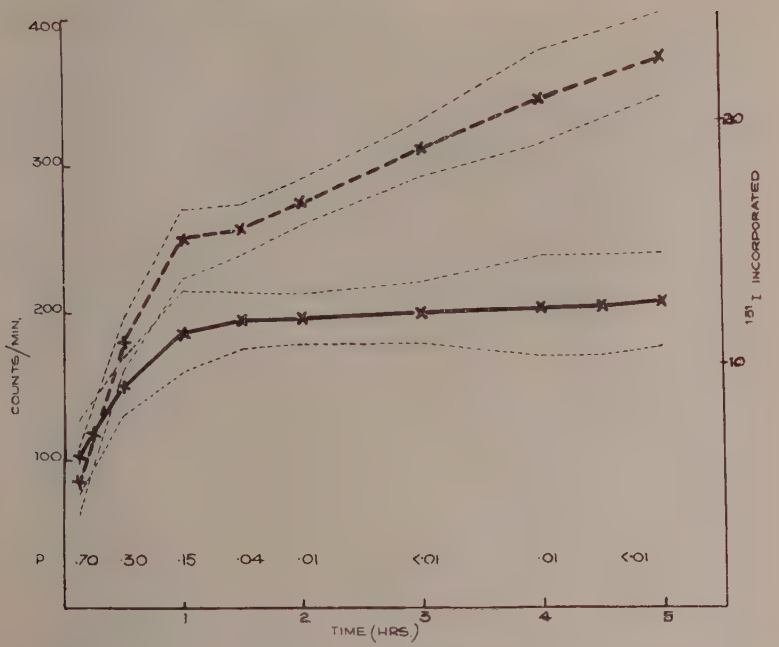


Fig. 2.—Levels of ^{131}I activity of the thyroids of rats fed freeze-dried CN and non-CN clover, at various times after ^{131}I injection. Full line: animals fed non-CN clover. Dashed line: animals fed CN clover. Dotted lines are drawn one standard error each side.

At the end of the experiment the thyroid glands were dissected from the rats and ^{131}I contents determined. Those from the rats fed the non-CN clover showed 194 $\pm$ 29 counts per min.* and those from the rats fed CN clover 341 $\pm$ 27, the difference being highly significant.

Thiocyanate analyses on the pooled rat blood showed the following end-levels:—

Non-CN clover group 6.4 mg. SCN per 100 ml. serum.
CN clover group 15.6 mg. SCN per 100 ml. serum.

Thiocyanate Injection Experiment

In early experiments the rats were dosed with potasium thiocyanate in quantities ranging from 25 to 250 mg. SCN. In all cases a marked inhibition of the time course of the incorporation of ^{131}I into the thyroids was observed, but since the levels of thiocyanate in the sera were considerably higher than those observed in the three feeding experiments, these results will not be presented in detail.

In Figs. 3 and 4, the ^{131}I incorporation curves are shown for two experiments in which thiocyanate was administered subcutaneously at levels of 0, 12.5, 17.5 mg. SCN respectively, there being 3 rats per treat-

* The data for one rat were discarded following a test of this result as an outlying observation which gave a "t" value of 18.8 for 4 d.f. ($P = 0.001$). This rat was also omitted in the construction of Fig. 2.

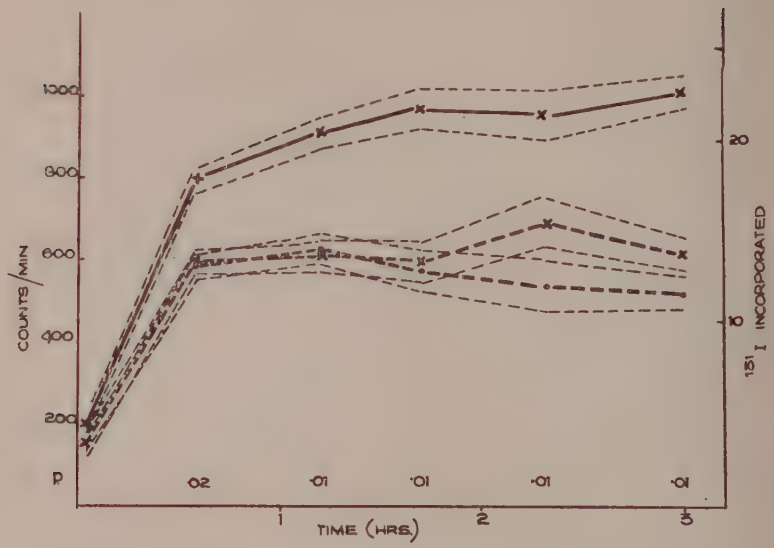


Fig. 3. —Levels of ^{131}I activity of the thyroids of rats which were injected subcutaneously with potassium thiocyanate at a mean time of 0.86 hours before ^{131}I injection. Full line: control group. Dashed line and crosses: 12.5 mg. SCN injected. Dashed line and dots: 17.5 mg. SCN injected. Dotted lines are drawn one standard error each side.

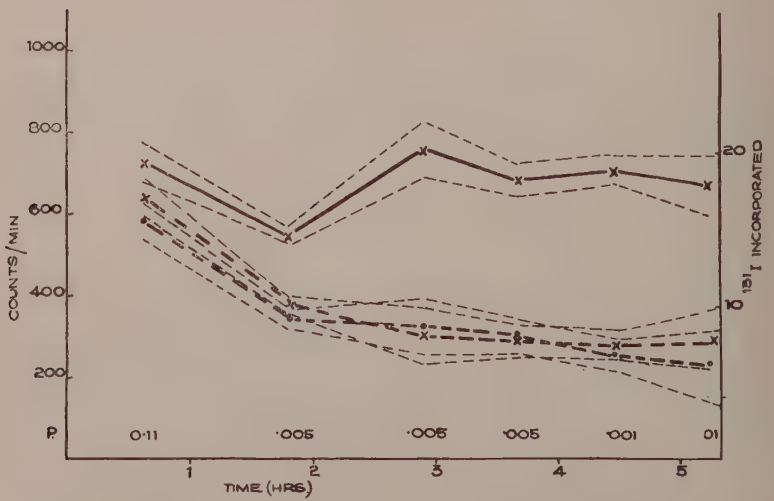


Fig. 4.—Levels of ^{131}I activity of the thyroids of rats which were injected subcutaneously with potassium thiocyanate at a mean time of 0.64 h. before ^{131}I injection. Full line: control group. Dashed line and crosses: 12.5 mg. SCN injected. Dashed line and dots: 17.5 mg. SCN injected. Dotted lines are drawn one standard error each side.

ment. The data are presented in Table 4. As the rats were brought to the counter in sets, (that is, each group of 3 animals covered all treatments), the following interpolation procedure was adopted. All counts were interpolated to the mean time for each set of 3 rats by assuming rate of change of count to be constant over the interval in question. The average time interval between the time of count and time used in interpolating was only 0.03 h. In analysis, set effects were removed and tests of significance done by analysis of variance in the usual way. The times given are the means of the 3 times for each set used in interpolation.

TABLE 4. THE INCORPORATION OF ^{131}I IODIDE INTO THE THYROIDS OF RATS, AFTER SUBCUTANEOUS INJECTION OF 0, 12.5 AND 17.5 MG. SCN

Time (h.)	Treatment Means			SE Mean ±	C.V.%	Significance of C v Tr Comparison P=
	Control	12.5 mg.	17.5 mg.			
Experiment 1						
0.03	206	155	158	36	28.4	—
0.57	794	595	585	31	8.1	0.02
1.19	912	612	627	37	9.0	0.01
1.69	970	595	574	50	12.2	0.01
2.32	954	693	538	61	14.4	0.01
3.00	1007	616	520	41	10.0	0.01
Experiment 2						
0.62	730	642	583	48	12.8	0.11
1.80	548	379	344	24	9.8	0.005
2.90	761	303	325	69	26.0	0.005
3.66	687	291	302	40	16.3	0.005
4.47	711	280	257	37	15.3	0.001
5.24	673	290	229	73	30.2	0.01

It will be seen that there is a depression of the incorporation of ^{131}I into the thyroids of the treated animals—at no stage were there any significant differences between the 12.5 mg. and 17.5 mg. counts. In Experiment 1, the differences at 2.32 h. and 3.00 h. were tested and gave probabilities of 0.15 and 0.19 respectively.

In Experiment 1, regression lines were fitted to the data from 0.50 h. onwards and gave the following regression coefficients:

Control group + 77.3 ± 25.1 counts/min./h. (highly significant)
12.5 mg. group + 17.8 ± 22.5 counts/min./h. (not significant)
17.5 mg. group — 37.5 ± 21.4 counts/min./h. (not significant)

Thus the count did not change significantly over the period in either of the treated groups, but increased significantly in the control group.

In Experiment 2, there was no significant change in counts per min. for the control group; however, in both of the treated groups there were significant regressions. In the 12.5 mg. group, Fs of 149.5*** and 60.81** for (1,15) d.f. were obtained for linear and curvilinear terms respectively, while the corresponding values in the 17.5 mg. group were 37.38** and 6.03* for (1,14) d.f. Thus in these two groups the counts min. dropped at a significantly decreasing rate during the trial period.

The difference in the two experiments for the first ^{131}I count recorded for the treated groups can be concluded to be due to a difference in the time of onset of the thiocyanate block. In Experiment 1 the mean difference in time between the thiocyanate and the radio-iodine injections was 0.86 h., compared with 0.64 h. in Experiment 2.

The levels of thiocyanate in the sera of the rats at the conclusion of the two experiments are shown in Table 5. It will be seen that the thiocyanate contents are comparable with those observed in the feeding experiments.

TABLE 5. FINAL LEVELS OF THIOCYANATE IN SERA OF RATS IN THE THIOCYANATE INJECTION EXPERIMENTS 1 AND 2 (mg. SCN per 100 ml. serum)

Treatment	Experiment 1	Experiment 2
0 mg. SCN	8.0	8.0
12.5 mg. SCN	20.0	18.0
17.5 mg. SCN	33.0	22.0

Sheep Feeding Experiment

Fig. 5 shows the variation in levels of serum thiocyanate at intervals throughout the feeding experiment. It will be seen that the animals all showed a basic level of thiocyanate having a mean value of 2.32 ± 0.11 mg. per 100 ml. serum before treatment. The animals fed CN white clover contained a markedly higher level of thiocyanate with a maximum level of 17.6 mg. per 100 ml. serum and a mean level of 8.3 ± 0.9 mg. per 10 ml. serum.

The data from the 8th to the 44th day were examined for regressions of thiocyanate level on time. The results were:

Sheep 1, 2 (fed red clover): Rate of increase of thiocyanate level per day 0.041 ± 0.008 mg. SCN per 100 ml. serum.

Sheep 3, 4 (fed CN white clover): Rate of increase of thiocyanate level per day 0.255 ± 0.060 mg. SCN per 100 ml serum. The difference between the group means (eliminating the upward trend in the control readings) was 0.214 ± 0.064 mg. SCN per 100 ml. serum per day (highly significant).

The steady increase in the thiocyanate levels of the sheep fed CN white clover could be attributed either to a steady increase in the cyanoglucoside content of the herbage or to a slow rate of excretion

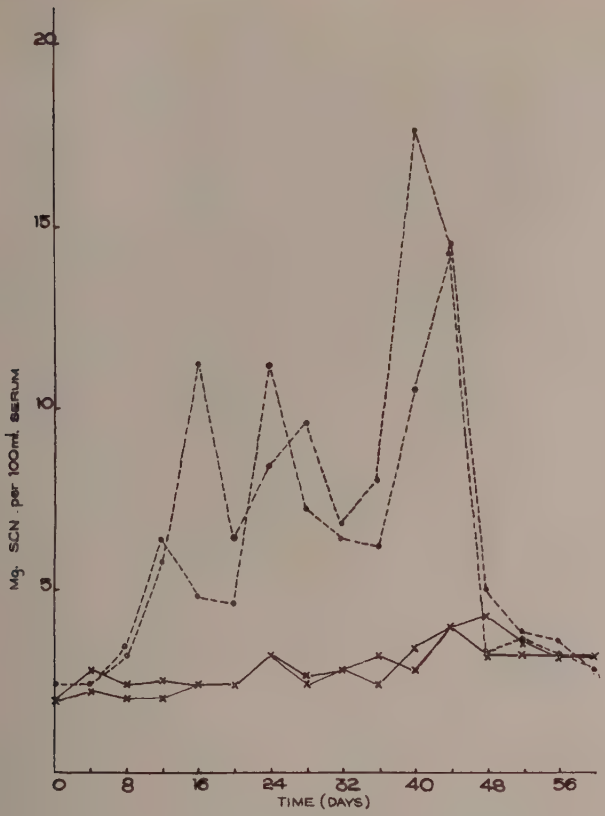


Fig. 5.—Serum thiocyanate levels in sheep feeding experiment. Crosses represent data from two sheep which received red clover 0 to 52 days and were starved from 53 to 58 days. Dots represent data from two sheep which received red clover from 0 to 8 days, CN white clover from 9 to 44 days, red clover from 45 to 52 days, and were starved from 53 to 58 days.

of thiocyanate by the animals. The slight increase with time of the serum thiocyanate level of sheep fed red clover throughout was unexpected; it could not be attributed to a change in sensitivity of the chemical determination.

DISCUSSION

As expected, the CN white clover showed a fairly high level of cyanogenetic glucosides, and the clover used as a control showed little or none. The wide difference in the iodine contents of the two types of clover (which were grown on adjacent areas not differing in soil type) was not known at the time of commencement of the project. Considerable differences in iodine content have since been found in various grass and clover strains and species grown under the same conditions and this is the subject of a separate communication (Johnson and Butler, in preparation).

With reference to the guinea-pig feeding experiment it is clear from the data on total thyroid iodine and thyroid cell heights that the CN white clover had produced a goitrogenic effect despite a higher total level of iodine in the diet. Astwood (1943) and others have shown that when additional iodide is given to rats the goitrogenic action of thiocyanate is overcome. It is not known what proportion of the iodine in the clovers was available to the animals, but unless there was a very great difference in iodine availability it seems likely that the higher iodine content of the CN clover would counteract to some extent any goitrogenic action of thiocyanate. Since the serum thiocyanate levels of the guinea-pigs fed CN clover were higher than those for the control group, there seems to be no evidence against the hypothesis that the effect seen was produced by the thiocyanate formed in the detoxication of cyanide from the CN glucoside in the clover. The possibility that some other goitrogen may have been responsible has not, however, been excluded.

The rates of uptake of ^{131}I by the thyroids of both guinea-pigs and rats in the two feeding experiments (Figs. 1, 2) appear at first sight to contradict the above interpretation, the levels of ^{131}I in the thyroids being greater in the animals that had been fed CN clover. But it is apparent from the other data presented that the administration of the goitrogen during the feeding period was sufficiently prolonged to induce changes in the cytology and total I content of the thyroid—changes which would be expected to restore the "normal" overall iodine exchange of the gland, but not to lead to an enhanced exchange.

It could be argued, however, that if the SCN/I balance of the blood of animals fed CN clover were altered in favour of I uptake (owing to the experimental conditions obtaining during radio-iodine incorporation) higher incorporations of ^{131}I might be expected for these animals. Such conditions could result either from restriction of intake of CN clover during the experiment or from the presence of added carrier iodide. In the guinea-pig feeding experiment, 0.8 μg. carrier iodide was present; no carrier was added in the rat-feeding experiment.

It has been shown by Wolf *et al.* (1946) that for a period after thiocyanate administration ceases thyroidal uptake of ^{131}I is increased. In the case of the guinea-pigs, this occurred because of the preliminary fast and later feeding on non-cyanogenetic material. In the case of the rats, there may have been a voluntary reduction in food intake in the early morning before the experiment. After preparation for the experiment, injection of ^{131}I, and the first light anaesthetization with ether, they fed little if at all. This explanation must be regarded as only tentative, however, as at the end of the experiment the guinea-pigs and rats that had been fed CN clover still showed a considerably higher level of thiocyanate in the serum than did the controls. In the experiment of Wolf *et al.* (1946) with rats, thiocyanate inhibition of uptake of thyroidal ^{131}I was shown only if thiocyanate was injected within 5 hours of the ^{131}I injections. The remaining animals that had been dosed earlier with the goitrogen, either by injection or orally, showed serum thiocyanate levels no higher than those of the controls. More data on the threshold levels of serum thiocyanate necessary to affect thyroidal uptake of ^{131}I is therefore required.

Some information on this question was obtained from the thiocyanate injection experiments presented above (Figs. 3, 4), since

it is shown that a marked inhibition of incorporation of ^{131}I into the thyroid results when the level of thiocyanate per 100 ml. rat serum is increased abruptly from 8 to 19 mg. This increase is of the same order as the difference in thiocyanate levels observed in the rat and guinea-pig feeding experiments. A desirable extension of this experiment would be to maintain rats for 10 to 14 days at a similar level of serum thiocyanate (by periodic subcutaneous thiocyanate injections); ^{131}I curves measured at a suitable interval after the last injection might then resemble those obtained in the two feeding experiments.

From the sheep-feeding experiment (Fig. 5), the conclusion can be drawn that the levels of thiocyanate in the serum of ruminants grazing on CN white clover can increase by the same amount as did the levels of thiocyanate in the guinea-pig and rat feeding experiments. If the uptake of iodine by the sheep thyroid is sensitive to inhibition by thiocyanate to the same degree as in the smaller animals, a goitrogenic effect at these levels of thiocyanate can be expected when the iodine intake of the animals is low. This is being tested experimentally.

The position in the field may be complicated by at least two additional factors under conditions of low iodine intake by the grazing animals. High intakes of calcium and of sodium chloride have both been demonstrated to be goitrogenic to laboratory animals in such circumstances (Taylor, 1954; Axelrad, Leblond, and Isler, 1955). Because of the generally high aerial deposition of sodium chloride on New Zealand pastures (J. G. Fraser*, pers. comm.) the possibility of an effect on thyroid function from this source particularly warrants investigation.

It is not yet known at what level of depression of thyroid activity the productive performance of animals begins to be adversely affected. In the present experiments the CN clover had little or no adverse affect on the growth of young guinea-pigs; but this may not be the case for other animal species, for functions other than growth, or for guinea-pigs capable for other reasons of growth at a greater rate.

A point of some importance is that definite quantities of thiocyanate (ranging from 2.0 mg. SCN per 100 ml. serum in sheep to 8.0 mg. SCN in rats) were consistently observed in the sera of normal animals in the control groups. A level of 4.2 mg. SCN per 100 ml. serum was found in an isolated analysis of pooled human sera. No evidence for lack of specificity for thiocyanate of the analytical method could be found. Hence the goitrogenic effect of thiocyanate in these experiments was the result of a relatively slight increase in the level of a normal blood constituent. Also, analysis of the sera of grazing animals for thiocyanate could provide a reliable index of the likelihood of a deleterious effect of white clover feed upon thyroid function in areas of low or marginal I.

Acknowledgements

It is with pleasure that the authors acknowledge the assistance of several persons in this work: Dr. C. P. McMeekan and Dr. I. J. Cunningham for provision of laboratory animals; Mr. L. W. Gorman for provision of clover material; Mr. C. W. S. Reid for assistance, especially in the sheep feeding experiment; and Misses C. Bray and M. Knowles and Messrs. W. Bennett, D. Collis, and P. Vlieg for

* Plant Chemistry Laboratory, Palmerston North.

technical assistance. We are grateful to Dr. H. D. Purves and Dr. A. T. Johns for constructive discussion during the course of the experiments. The work was initiated while one of us (D.S.F.) was employed by the Dairy Research Institute (N.Z.), and this Institute continued to be interested throughout the work.

REFERENCES

ASTWOOD, E. B. 1943: The Chemical Nature of Compounds which Inhibit the Function of the Thyroid Gland. *J. Pharmacol. 78:* 79.

AXELRAD, A. A.; LEBLOND, C. P.; ISLER, H. 1955: Role of Iodine in the Production of Goitre by the Remington Diet. *Endocrinology 56:* 387.

BARKER, M. H.; LINDBERG, H. A.; WALD, M. H. 1941: Further Experiments with Thiocyanate. Clinical and Experimental Observations. *J. Amer. med. Ass. 117:* 1951.

BROWN-GRANT, K.; GIBSON, J. G. 1955: The Uptake of Radio-iodine by the Thyroid Gland of the Rabbit. *J. Physiol. 127:* 328.

CARE, A. D. 1954: Goitrogenic Properties of Linseed. *Nature 173:* 172.

COOP, I. E.; BLAKLEY, R. L. 1949: The Metabolism and Toxicity of Cyanide and Cyanogenetic Glucosides in Sheep. *N.Z. J. Sci. Tech. A30:* 277.

CORKILL, L. 1940: Cyanogenesis in White Clover (*Trifolium repens* L.). 1. Cyanogenesis in Single Plants. *Ibid. B22:* 65.

———1942: Cyanogenesis in White Clover (*Trifolium repens* L.). 5. The Inheritance of Cyanogenesis. *Ibid. B23:* 178.

———1952: Cyanogenesis in White Clover (*Trifolium repens* L.). 6. Experiments with High-glucoside and Glucoside-free Strains. *Ibid. A34:* 1.

COWDRY, E. V. 1948: "Laboratory Technique in Biology and Medicine" 2nd ed. p. 193. Williams and Wilkins, Baltimore.

FISTER, H. G. 1950: "Manual of Standardised Procedures for Spectrophotometric Chemistry". Standard Scientific Supply Corporation, New York.

GOLDBERG, R. D.; CHAIKOFF, I. L.; LINDSAY, S.; FELLER, D. D. 1950: Histopathological Changes Induced in the Normal Thyroid and Other Tissues of the Rat by Internal Radiation with Various Doses of Radioactive Iodine. *Endocrinology 46:* 72.

MELVILLE, J.; DOAK, B. W. 1940: Cyanogenesis in White Clover (*Trifolium repens* L.) 2. Isolation of the Glucosidal Constituents. *N.Z. J. Sci. Tech. B22:* 67.

MELVILLE, J.; COOP, I. E.; DOAK, B. W.; REIFER, I. 1940: Cyanogenesis in White Clover. 4. Methods of Determination and General Considerations. *N.Z. J. Sci. Tech. B22:* 144.

NOACH, E. L. 1955a: Influence of Oestrogens on Thyroid Function. I. *Acta endocr., Copenhagen. 19:* 127.

———1955b: Influence of Oestrogens on Thyroid Function. II. *Ibid. 19:* 139.

RAWSON, R. W.; TANNHEIMER, J. F.; PEACOCK, W. 1944: The Uptake of Radio-active Iodine by the Thyroids of Rats Made Goiterous by Potassium Thiocyanate and by Thiouracil. *Endocrinology 34:* 245.

SULLIVAN, J. T., 1939: Determination of HCN by the Picric Acid Method and the KNSZ Photometer. *J. Ass. off. agric. Chem. Wash. 22:* 781.

TAUROG, A.; CHAIKOFF, I. L. 1946: On the Determination of Plasma Iodine. *J. biol. Chem. 163:* 313.

TAYLOR, S. 1954: Calcium as a Goitrogen. *J. clin. Endocrin. 14:* 1412.

WOLF, J.; CHAIKOFF, I. L.; TAUROG, A.; RUBIN, L. 1946: The Disturbance in Iodine Metabolism Produced by Thiocyanate: the Mechanism of its Goitrogenic Action with Radioactive Iodine as Indicator. *Endocrinology 39:* 140.

OBSERVATIONS ON THE BIOLOGY OF CALLIPHORIDS IN NEW ZEALAND

By M. D. Murray*, Wallaceville Animal Research Station, Department of Agriculture, Wellington

(Received for publication, 10 February 1956)

Summary

Observations on three years' trapping using a Western Australian type of trap with liver bait are recorded. The significance of some of the findings in relation to the sheep blowfly problem in New Zealand is discussed.

Introduction

In the past, work on the Calliphorid flies in New Zealand has been confined mainly to systematics, with the result that our knowledge of the ecology of this group of flies is very scanty. Thus it was considered desirable, before any work on the entomological aspects of the blowfly problem could be commenced, that some general information on the ecology of the Calliphorids should be sought. To this end, trapping experiments were carried out at Wallaceville during the period June 1950 to December 1953, and this paper presents some of the findings.

Experimental Procedure

The Research Station farm at Wallaceville, around which the traps were placed, is situated in the upper part of the Hutt Valley, an area which is rapidly becoming settled. The farm itself covers 100 acres and is continuous with the Trentham race course. One side is bounded by a range of hills, which rise to 800 ft., and are for the most part covered in dense manuka scrub with some beech bush on the lowest slopes. The other side is bounded by the railway line, beyond which the existing housing area is expanding rapidly towards the Hutt River on the far side of the valley. The trapping area was essentially that of a rural environment.

During the first year, June 1950 to July 1951, six traps of the Western Australian pattern were used, each being placed in a different situation. Ecologically, the situations of the traps fell into two groups, those associated with bush and those associated with the open paddock. From July 1951 to December 1953 only two of these traps, one bush and one paddock, were operated.

All were baited with a pound of fresh sheep's liver and a pint of water without any chemicals added to enhance the attractiveness of the bait or prevent the development of maggots within the bait. The trapping period was one week and collections were made every 3 to 5 weeks throughout the year. At first, total counts of every trap were made, but when catches became too large, quarter samples were taken for counting, using a Riffle sampler, a method which proved very satisfactory. The whole catch of every trap was always examined to obtain specimens of the less common flies.

* Present address: McMaster Animal Health Laboratory, C.S.I.R.O., Sydney, Australia.

Results

Species of Flies Captured

As a basis for taxonomic work, Miller's (1939a) descriptions of the New Zealand blowflies were used and all the common species fitted the keys readily. However, as a result of finding a new species *Calliphora neozealandica* Murray a new key was devised (Murray 1954). The nomenclature used in this paper is that used by Murray (1954) for the *Calliphora* and that of Miller (1950) for all other flies. In this connection it should be noted that *Calliphora stygia* Fabricius is synonymous with *C. laemica* (White).

The following species were captured:

CALLIPHORIDAE

Calliphora rufipes Macquart
C. stygia Fabricius (= *C. laemica* White)
C. quadrimaculata (Svederus)
C. erythrocephala (Meigen)
C. icela (Walker)
C. hortona (Walker) (one specimen only)
C. neozealandica Murray
Chrysomyia rufifacies (Macquart)
Lucilia sericata Meigen
Huttonophasia pernix (Hutton)
Pollenia spp.

MUSCIDAE

Calliphoroides antennatis (Hutton)
Musca domestica Linnaeus
Muscina stabulans (Fallen)
Neoperonia analis (Macquart)

TACHINIDAE

Sarcophaga milleri Johnston & Hardy

It was not possible to examine all the specimens of *Lucilia,* but those examined all proved to be *Lucilia sericata.*

Variations in the Number of Flies Captured

Most flies were caught in the traps associated with bush, and the total catches of all traps followed the same general pattern in that the greatest numbers of flies were caught in the summer months.

Flies found throughout the year:—

Calliphora rufipes
C. stygia
C. quadrimaculata
C. icela
C. erythrocephala
Calliphoroides antennatis

Flies not found in the winter months:—

Lucilia sericata
Chrysomyia rufifacies
Sarcophaga milleri
Neoperonia analis

In Fig. 1 may be seen the trends taken by five species of flies, *C. rufipes, C. stygia, C. quadrimaculata, C. icela* and *Lucilia sericata.*

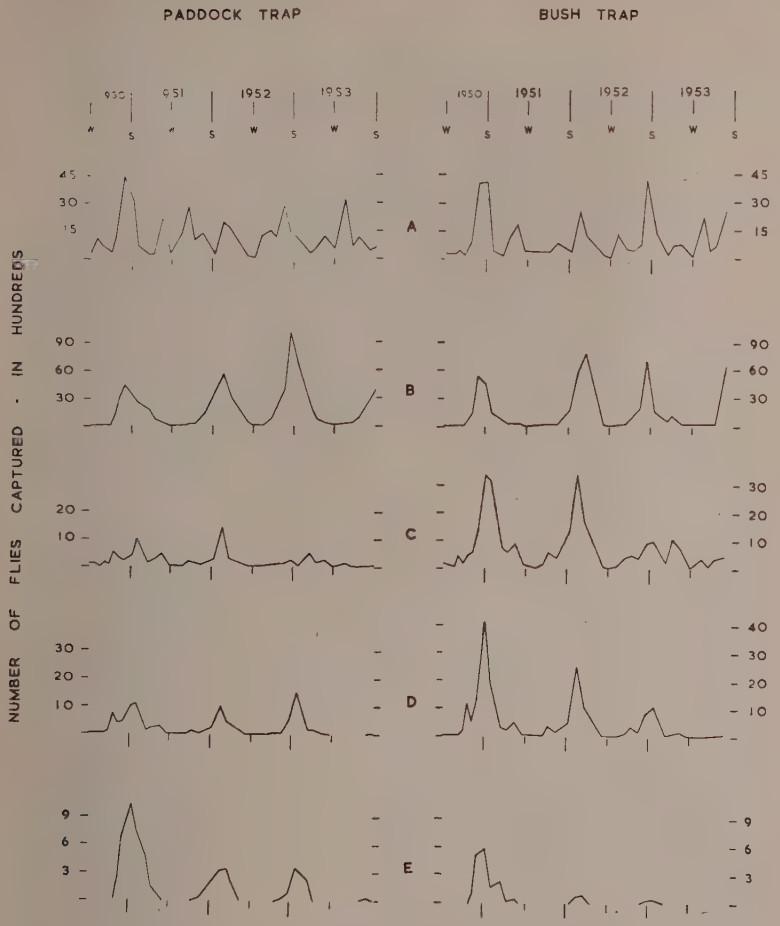


Fig. 1.—Seasonal fluctuation in the number of blowflies captured at Wallaceville.

A. *C. quadrimaculata;* B. *C. icela;* C. *C. rufipes;* D. *C. stygia;* E. *L. sericata;* W. winter; S. summer.

C. quadrimaculata and *C. icela* were caught in greatest numbers and *C. quadrimaculata* in considerable numbers throughout the winter. Both flies showed no trap preference. *C. icela* showed a very distinct summer peak.

C. rufipes and *C. stygia* were both caught in largest numbers in those traps associated with bush.

Lucilia sericata, which was first caught in the spring, showed a preference for the paddock traps, and appreciable numbers did not appear until the early summer months. *Chrysomyia rufifacies* appeared first in the early summer and increased very rapidly to a peak in late summer, disappearing shortly afterwards.

Relatively few *Calliphora erythrocephala* were caught at Wallaceville and most of these were trapped in the early summer.

Of the non-calliphorid flies, *Calliphoroides antennatis* showed a preference for the bush traps but *Sarcophaga milleri* preferred the paddock traps. This is what might have been expected as *S. milleri* is very common in the paddocks during the summer months where it breeds in the cow dung. *Neoperonia analis* was found in all traps but only in any numbers during the summer months.

Discussion

In New Zealand there are two flies that can initiate blowfly strike in sheep. These are *Calliphora stygia* which is viviparous and *Lucilia sericata* which is oviparous. At present we know little of the nature of the stimuli that attract them to sheep or stimulate larviposition or oviposition and therefore play a large part in determining their relative importance. Neither do we know how this attraction to sheep is enhanced or counteracted by the conditions met within the fleece, or what conditions favour the deposition of larvae rather than eggs or vice versa. However, from what we do know it is felt that an explanation for certain field observations can be offered.

Blowfly strike may occur throughout the whole year, but two main periods for blowfly strike are recognized. The first is in spring and early summer when crutch strike predominates, and the other is during the autumn when body strike may predominate. The reasons for the two periods are, firstly, that in the winter the fly populations are reduced, and, secondly, that shearing, which take place early in the summer, renders the sheep unattractive to the flies until late summer when the fleece has regrown.

In some districts, such as Poverty Bay, cases of strike caused by *Calliphora stygia* are not uncommon throughout the winter months. The presence of *C. stygia* during the winter months has been observed in the past and is confirmed by the trapping experiments at Wallaceville. Thus, it is not surprising that these cases occur if the sheep is attractive to the fly.

Following this observation further, it might be expected that *C. stygia* is more important when the sheep become attractive in the early spring. Miller (1939b) after the study of maggots from struck sheep, considered that *C. stygia* was the main fly responsible for striking sheep in the spring period with *Lucilia sericata* striking only later in the year. Macfarlane (1942) working in Marlborough also comments on the *L. sericata* strikes occurring only later in the year. Maggot collections (Murray, unpublished data) from struck sheep in 1950–51 in the Poverty Bay area showed a similar trend, the *L. sericata* strikes not occurring until December. More maggot collections are desirable, but all available evidence indicates that *C. stygia* is active at an earlier date than *L. sericata*. This certainly was so at Wallaceville and Poverty Bay in 1950–51. Thus *L. sericata* was only present in any numbers for the latter part of the crutch strike period.

The part played by these two flies in the autumn period is far from clear but the increase in the number of *L. sericata* strikes has been well established. During this period there are numerous cases of body strike, the main predisposing cause of which appears to be fleece rot or mycotic

dermatitis, and Macfarlane (1942) has suggested that, in New Zealand, *L. sericata* is more attracted to this than urine staining of the crutch. Such questions cannot be answered for the present, but excluding differences in the attraction to sheep the following factors appear to be important.

For fleece rot and mycotic dermatitis to develop, climatic conditions of warmth and moisture with high humidity are required. These same conditions are usually favourable to fly populations. Thus, should such favourable conditions develop in late summer (February) the *L. sericata* population could be maintained. This would be influenced by the survival of their larvae in carrion. However, should such favourable conditions not develop until the late autumn (April, May) the *L. sericata* population would have declined or disappeared and only the *C. stygia* population would respond. Macfarlane (unpublished data 1938) comments on this in a report on a body strike wave caused by *C. stygia* in Canterbury (April, May 1938). No *Lucilia* has been caught in traps since April and he states:

> "From the traps it was observed that *C. stygia* was more abundant during the strike period than during the previous month . . ."

The preference of *C. stygia* for the bush-traps is of interest as it is generally stated by sheep farmers in Poverty Bay, where this fly is the more important, that body strike in the autumn, and indeed at other times of the year, occurs mostly in paddocks containing scrub. This is due in all probability to two factors. First, scrub maintains conditions of humidity and moisture which favour the development and maintenance of fleece attractiveness and secondly there is an increased fly population in such situations.

Although many more critical field experiments must be planned to study the biology of these introduced flies in relation to their various New Zealand habitats, in the light of our present knowledge it is suggested that in those parts of the country where both *Calliphora stygia* and *Lucilia sericata* are present their relationship to the blowfly problem, as a whole, is as follows:

1. Sheep are struck only when they are attractive to the flies concerned and that the predisposing causes are in the main similar to those recorded by overseas workers.
2. The time of year of the development of this attractiveness determines the relative importance of each species of blowfly.
3. When both species are abundant, the main factors are climatic conditions and the type of country on which the sheep are run. Climatic conditions determine the development of fleece attractiveness whereas the type of country determines how long such attractiveness may be prolonged and the species of fly striking.

ACKNOWLEDGEMENTS

I should like to take this opportunity to thank all those who have assisted me in counting the flies in the catches. In particular I should like to thank Mr. L. K. Whitten, Parasitologist, Wallaceville Animal Research Station, who continued to operate two traps for two and a half

years after my departure from his Section in 1951 and has allowed me to use these results in completing this paper. I should further like to thank Mr. Whitten for his assistance in the preparation of this paper.

REFERENCES

MACFARLANE, W. V. 1942: Blowfly Strike in Marlborough, N.Z. *N.Z. J. Sci. Tech. A23:* 205-13.

MILLER, D. 1939a: Blowflies (Calliphoridae) and their Associates in in New Zealand. *Cawthron Inst. Monogr. 2.*

————1939b: Sheep Maggot-fly Problem. New Zealand Survey, 1937-38. *N.Z. J. Sci. Tech. A21:* 240-4.

————1950. Catalogue of the Diptera of the New Zealand Subregion. *N.Z. Dep. sci. industr. Res. Bull. 100.*

MURRAY, M. D. 1954: *Calliphora neozealandica* sp. nov., a New Blowfly from New Zealand. *Trans. roy. Soc. N.Z. 82:* 713-20.

PUBLICATION RECEIVED

Potassium symposium 1954. Berne, International Potash Institute, 1955. 445p. 15 Sw. frs.

This symposium consists of 21 papers read at the Annual meeting of the Board of technical advisers of the Institute. There were four sessions covering Potassium in the soil, Potassium in the organisms, Potassium in agriculture and Potassium analysis. The papers are in English, German or French and each paper has a summary in each of these languages and also in Spanish. The conclusions are printed in these four languages as is the subject index.

BULLETINS OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

No.

5. PLANT-BREEDING METHODS AND RESULTS. F. W. Hilgendorf. Price, 6d.
6. REPORT ON THE FISCHER PROCESS. H. O. Askew. Price, 6d.
8. SUMMARY OF INVESTIGATIONS ON NEW ZEALAND COAL. W. Donovan. Price, 6d.
11. BUILDING STONES OF NEW ZEALAND. P. Marshall. Price, 4s.
13. YIELD OF CHEESE PER POUND OF BUTTERFAT. P. O. Veale. Price, 9d.
14. LOW TEMPERATURE CARBONIZATION OF NEW ZEALAND COALS. 1. WAIKATO COAL. W. A. Joiner. Price 9d.
16. COLD STORAGE OF FRUIT INVESTIGATIONS OF 1927 AND 1928. L. W. Tiller. Price 6d.
17. PIG RECORDING, BACON-MANUFACTURE, AND THE PIG INDUSTRY IN NEW ZEALAND. M. J. Scott, C. R. Barnicoat, and F. R. Callaghan. Price, 1s. 6d.
20. LOW TEMPERATURE CARBONIZATION OF NEW ZEALAND COALS. 2. KAITANGATA AND LINTON COALS. W. A. Joiner. Price, 6d.
23. RELATION OF STORAGE TEMPERATURE TO THE OVERSEAS CARRIAGE OF SOME VARIETIES OF NEW ZEALAND EXPORT APPLES. L. W. Tiller. Price, 6d.
24. A CLASSIFICATION OF THE WAIKATO TYPE OF COAL. W. H. Penseler. Price, 1s. 9d.
25. BRONZE BEETLE RESEARCH. A. M. Lysaght. Price, 1s. 6d.
26. INFLUENCE OF SEASON AND FERTILIZER ON THE YIELD AND COMPOSITION OF TYPICAL DAIRYING PASTURES. T. Rigg. Price, 2s.
28. WHEAT RESEARCH INSTITUTE: FIRST ANNUAL REPORT, 1929-30.
29. LOW TEMPERATURE CARBONIZATION OF NEW ZEALAND COALS. 3. MILLERTON AND BLACKBALL COALS. W. A. Joiner. Price, 1s.
30. WOOL RESEARCH.
31. INVESTIGATIONS INTO PASTURE PRODUCTION. A. W. Hudson. Parts I, II, III, issued. Price, 5s.
32. BUSH SICKNESS. H. O. Askew, T. Rigg, L. I. Grange, N. H. Taylor, and others. Price, 2s. 9d.
33. BUTTERFAT LOSSES IN BUTTERMILK. W. H. Udy. Price, 1s.
34. NUTRITIVE VALUE AND VITAMIN EFFICIENCY OF NEW ZEALAND DAIRY PRODUCE. M. G. Frengley and M. M. Herrick.
39. BRIQUETTING OF NEW ZEALAND COALS. W. A. Joiner, W. G. Hughson, and A. K. R. McDowell. Price, 9d.
44. THE COMMERCIAL RIPENING OF BANANAS IN NEW ZEALAND. J. B. Hyatt and C. W. O. Turner. Price, 1s.
45. GOITRE IN SCHOOL-CHILDREN. R. A. Shore and R. L. Andrew. Price, 1s. 6d.
46. "CROSS 7" WHEAT. O. H. Frankel. Price, 1s.
48. WATER-SUPPLIES OF FARMS AND DAIRY FACTORIES IN HAMILTON BASIN AND HAURAKI LOWLAND. N. H. Taylor. Price, 1s. 6d.
50. THE CHEESE YIELDING CAPACITY OF MILK. F. H. McDowall. Price, 3s. 6d. (Obtainable from the Dairy Research Institute, Massey College, Palmerston North.)
51. THE CHILLING OF BEEF FOR EXPORT. C. R. Barnicoat. Price, 1s. 3d.
52. INVESTIGATION OF FEED FLAVOUR IN CREAM AND BUTTER. W. Riddet, E. Bruce Levy, and others. Price 1s.
53. A PRELIMINARY SURVEY OF THE CITRUS INDUSTRY IN NEW ZEALAND.
55. THE WEST NELSON EARTHQUAKE OF 1929.
57. REPORT OF INTERDEPARTMENTAL COMMITTEE ON SILICOSIS. Price, 1s. 3d.
60. PETROLEUM IN NEW ZEALAND. J. Henderson. Price, 1s.
61. THE SOILS AND AGRICULTURE OF WESTERN SAMOA. W. M. Hamilton and L. I. Grange. Price, 1s.
62. LAND DETERIORATION IN THE HEAVIER RAINFALL DISTRICTS OF NEW ZEALAND. N. H. Taylor.
63. REPORT ON THE ORGANIZATION OF ANIMAL RESEARCH IN NEW ZEALAND. J. Hammond. Price, 1s.
65. SOIL SURVEY OF DUVAUCHELLE BAY - WAINUI DISTRICT, BANKS PENINSULA. C. S. Harris and A. G. Harris. Price, 1s. 3d.
66. A SURVEY OF TUNG GROVES IN NEW ZEALAND. M. M. Burns and N. H. Taylor. Price, 2s.
67. A LIST OF PLANT DISEASES RECORDED IN NEW ZEALAND. R. M. Brien. Price, 1s.
69. SCIENTIFIC AND INDUSTRIAL RESEARCH, 1927-38. Price, 2s. 6d.
71. SOIL SURVEY OF WESTPORT DISTRICT. C. S. Harris and A. C. Harris. Price, 1s. 6d.
72. SOIL SURVEY OF WAIRAU PLAINS, MARLBOROUGH. C. S. Harris and K. S. Birrell. Price, 2s.
74. SOME GROUND-WAVE FIELD-INTENSITY MEASUREMENTS TAKEN IN NEW ZEALAND. G. Searle. Price, 1s.
75. A SURVEY OF THE STANDARDS OF LIFE OF NEW ZEALAND DAIRY-FARMERS. W. T. Doig. Price, 2s. 6d.
80. THE CURING AND COLOURING OF NEW ZEALAND LEMONS. J. B. Hyatt and O. H. Keys.
82. BOTANICAL ASPECTS OF RAGWORT (SENECIO JACOBAEA L.) CONTROL. A. L. Poole and D. Cairns. Price, 2s. 6d.

BULLETINS OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH—Continued

No.

84. WHEAT RESEARCH INSTITUTE: SEVENTH ANNUAL REPORT. Price, 1s.
86. MOLE DRAINAGE IN NEW ZEALAND. A. W. Hudson and H. G. Hopewell.
88. FIRECLAY AND GANISTER IN NEW ZEALAND. J. Henderson. Price, 2s. 6d.
90. MILBURN-CLARENDON PHOSPHATE DEPOSITS. E. O. Macpherson. Price, 2s. 6d.
91. NASSELLA TUSSOCK. A. J. Healy. Price, 2s. 9d.
92. SOIL EROSION IN THE HIGH COUNTRY OF THE SOUTH ISLAND. H. S. Gibbs, J. D. Raeside, J. K. Dixon, and A. J. Metson. Price, 5s.
93. INVESTIGATION OF THE CLARENDON PHOSPHATE DEPOSITS. R. W. Willett. Price, 5s.
94. SOILS AND SOME RELATED ASPECTS OF AGRICULTURE IN MID HAWKE'S BAY. I. J. Pohlen and others. Price, 5s.
95. SOIL EROSION IN NEW ZEALAND—PART 1: SOUTHERN HALF OF NORTH ISLAND. L. I. Grange and H. S. Gibbs. Price, 2s. 6d.
96. RHYTHMS IN NEMATODE PARASITISM OF SHEEP. J. H. Tetley. Price, 8s. 6d.
97. REPORT ON BUILDING AND CIVIL ENGINEERING RESEARCH IN NEW ZEALAND. R. E. Stradling. Price, 2s. 6d.
98. INTRODUCED MAMMALS OF NEW ZEALAND. K. A. Wodzicki. Price, 12s. 6d.
99. POISONOUS PLANTS IN NEW ZEALAND. H. E. Connor. Price, 3s. 3d. (4s. quarter cloth).
100. CATALOGUE OF THE DIPTERA OF THE NEW ZEALAND SUB-REGION. D. Miller. Price, 13s. 6d.
101. A REVISED LIST OF PLANT DISEASES RECORDED IN NEW ZEALAND. R. M. Brien and Joan M. Dingley. Price, 5s.
102. A REVISION OF THE MELOLONTHINAE OF NEW ZEALAND. B. B. Given and J. M. Hoy. Price, 12s.
103. NEW ZEALAND-AMERICAN FIORDLAND EXPEDITION. Compiled by A. L. Poole. Price, 7s. 6d.
104. A STATISTICAL STUDY OF LINEN FLAX CROP RECORDS. G. M. Wright. Price, 2s. 6d.
105. LIST OF NEW ZEALAND POLYCHAETES. Marion L. Fyfe. Price, 5s.
106. APHIDS OF NEW ZEALAND. W. Cottier. Price £2 2s. 0d.
107. ECOLOGICAL STUDY OF TUSSOCK GRASSLAND. A. P. Barker. Price, 6s.
108. PLANT VIRUS DISEASES IN NEW ZEALAND. E. E. Chamberlain. Price, Paper Cover 15s. Bound £1.
109. A CATALOGUE OF THE THYNNINAE OF AUSTRALIA AND ADJACENT AREAS. B. B. Given. Price, 6s.
110. EVALUATION OF EXTERIOR HOUSE PAINTS BY PANEL TESTS. G. Chamberlain. Price, 6s. 6d.
111. THE STORAGE OF APPLES AND PEARS. C. A. S. Padfield. Price, 8s. 6d.
112. DAIRY-FARM SURVEY OF WAIPA COUNTY 1940-41 TO 1949-50. J. B. Hutton. Price 6s. 6d.
113. THE ACADEMIC RECORD OF SCIENCE STUDENTS IN THE UNIVERSITY OF NEW ZEALAND. I. D. Dick, R. M. Williams, and Dermot Straker. Price, 6s. 6d.
114. DISEASES AND PESTS OF PEAS AND BEANS IN NEW ZEALAND AND THEIR CONTROL. R. M. Brien and others. Price 9s. 6d.
115. TRACE-ELEMENT DEFICIENCIES OF FRUIT CROPS IN NEW ZEALAND. E. G. Bollard. 6s. 6d.
116. A MANUAL OF THE SPORES OF NEW ZEALAND PTERIDOPHYTA. W. F. Harris. Price 23s.
117. GEOTHERMAL STEAM FOR POWER IN NEW ZEALAND. Compiled by L. I. Grange. Price 15s.
118. SHIPMENT OF CHILLED BEEF, 1952. N. H. Law and N. W. Vere-Jones. Price 7s. 6d. (quarter cloth 10s.)

NOTE: Numbers not listed above are out of print.

ALL PRICES POST FREE

Order through your Bookseller or from

THE PUBLICATIONS OFFICER, DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, P.O. BOX 8018, WELLINGTON

and from

THE HIGH COMMISSIONER FOR N.Z., 415 STRAND, LONDON, W.C.2

All Orders should be accompanied by remittance.

To country cheques add exchange (6d.)

Coulls Somerville Wilkie Ltd. 1,250-6-56